AN

ANALYSIS OF PHYSIOLOGY:

BEING

A Condensed View

OF ITS

MOST IMPORTANT FACTS AND DOCTRINES.

DESIGNED ESPECIALLY

FOR THE USE OF STUDENTS.

BY

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TO

SAMUEL JACKSON, M.D.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF PENNSYLVANIA, ETC., ETC.,

This Volume

IS DEDICATED, AS A TRIBUTE OF RESPECT

FOR HIS

DISTINGUISHED RANK AS A MEDICAL INSTRUCTOR,

HIS EMINENCE AS A PHYSICIAN,

AND

HIS EXCELLENT QUALITIES OF HEAD AND HEART,

BY THE AUTHOR.

PREFACE

TO THE SECOND EDITION.

THE first edition of this work, which appeared in 1847, was written at the solicitation of the author's class of students, who desired a convenient manual for their examinations on Physiology; —one which might present a plain though complete analysis of what was taught by the best authorities on that branch of medical science.

Since that period, many new and important facts have been developed by the untiring experiments of the physiologist, the physicist, and the organic chemist; and doctrines, which then had only begun to be put forth in the shape of speculative theories, may now be considered as sanctioned by the approbation of the highest names.

The call for another edition of this work has afforded the author the opportunity of introducing, so far as he could gain access to them, all the new and important discoveries. Some of these, it is true, require still farther confirmation before they can be admitted as established facts; for in proportion to the multiplicity of novelties in science, should care be exercised to subject them to the rigid test of experience. Hence, it is quite possible that some of the deductions contained in the present volume, may be compelled to yield to the results of more accurate future investigations.

The former edition was modelled very much after Dr. Carpenter's Manual of Physiology, republished in this country under the title of "Elements of Physiology." The present volume has

undergone an entire revision, and has been differently arranged; most of it, likewise, has been re-written, and much new matter added; so that the hope may be indulged that it may continue to prove useful to students of medicine, for whose benefit more especially it was prepared.

The author has not hesitated to avail himself freely of every source within his reach, from which to glean materials that might impart value or interest to his work. The recorded opinions of writers become, in a measure, the property of the scientific public; and it is but applying them to a legitimate use, when they are employed by others in the same field of research, provided always that due credit is given to their respective sources. To enumerate all these sources would not, in this place, be possible, so intimately are they interwoven with all the well-established doctrines of physiological science. Many of them are named in connexion with particular subjects, throughout the volume. The author desires to acknowledge his indebtedness for several of M. Bernard's recent experiments, to the very interesting contributions by Dr. Donaldson, of Baltimore, to the American Journal of Medical Sciences, for 1851. He would also embrace the occasion to express his obligation to the public lectures of Dr. Samuel Jackson, Professor of the Institutes of Medicine in the University of Pennsylvania, under whose valued instruction it has been his privilege to sit, and from whom he has imbibed many of the ideas contained in the following pages.

As regards the absence of illustrations from the work, a word or two will suffice: they would have considerably increased its expense, without, in the author's opinion, proportionally enhancing its value; inasmuch as they can be found in nearly every physiological treatise accessible to the student.

PHILADELPHIA, March, 1852.

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ANALYSIS OF PHYSIOLOGY.

PART I.

GENERAL INTRODUCTORY CONSIDERATIONS.

PHYSIOLOGY may be defined to be the science which treats of the actions peculiar to living, or organized beings.

All bodies in nature are susceptible of division into two great classes—the *inorganic*, and the *organic* or *organized*. The former includes the mineral kingdom; the latter, the vegetable and animal. The laws of physics govern the former class, while the latter is controlled by the laws of vitality and intelligence, together with the laws of physics.

It is not always easy precisely to define the limits which separate these different classes of objects, so insensibly do their extremes seem to merge into each other. Thus, although no one could confound an ordinary crystal with an herb or flower, or mistake a tree for a quadruped, he might be not a little perplexed to discriminate between the solid coral, and the rock to which it may be attached; or between one of the lowest polypi, scarcely evincing a rudiment of animality, and a vegetable.

Organic and inorganic bodies, nevertheless, exhibit many well-marked points of distinction. 1. *In form.* In organic bodies, the shape is constant and determinate for every species or race, allowance being made for individuals, and this shape is bounded by rounded outlines; inorganic bodies, on the contrary, are either undefined or shapeless in their form, or else occur in crystals, bounded by angles and straight lines. 2. *In origin.* Organized bodies always

spring from a parent, or germ; inorganic bodies are formed by the aggregation of particles of matter, by virtue of certain forces, as of cohesion, or chemical affinity. 3. *In internal structure.* Organic bodies are made up of different parts, or *organs*, each of which has a different texture,—the union of the whole being requisite for the perfection of the being; an inorganic body—a crystal, for example—may be divided into the minutest fragments, and yet each separate atom will be a perfect representative of the original. 4. *In size.* The size of inorganic masses is entirely indeterminate; that of organized bodies is, for the most part, restricted within certain limits. Departures from this rule are, however, seen in the lowest order of animal and vegetable life, as in the coral, the sea-weed, &c.; but, in most of these cases, the increase in size is dependent upon a continued production of *new* individuals, rather than upon a continued development of the same individual. 5. *In chemical composition.* The peculiarity of the chemical composition of organic bodies depends, not upon the presence of any elementary substances not found in the inorganic class, but upon the comparatively small number of these elements entering into their constitution. Of the sixty-two simple or ultimate elements found in the inorganic kingdom, about *eighteen* only exist in organic bodies; and of these, only *four* are regarded as *essential*, viz., carbon, oxygen, hydrogen, and nitrogen, —the remainder (termed *non-essential* or *accidental*) being introduced apparently for mechanical or chemical purposes. Some of these are extremely rare; others occur very frequently, and subserve important purposes in the living economy; thus, sulphur and phosphorus are found in albumen and fibrin; phosphorus and calcium, in the form of phosphate of lime, give hardness to bones; phosphorus is an integrant part of the brain; iron occurs as a constant ingredient of the blood; and so on.

The *tissues* of vegetables are found to be remarkably uniform in their chemical composition, consisting of a substance termed *cellulose*. This is a ternary compound of carbon, oxygen, and hydrogen, the two latter being in the proportion to form water.

The *inner* wall of the vegetable cell is composed of a nitrogenized substance, believed to be identical with the animal cell-wall.

Animal tissues consist essentially of two proximate nitrogenized principles—*proteine* and *gelatine*.

We shall, hereafter, allude to those proximate constituents of plants and animals, more in detail (Part II.); they are cursorily presented here, merely to complete the outline of the sketch intended to exhibit the points of difference between the organic and the inorganic kingdoms.—There are various other points of distinction, such as the mode by which vegetables and animals derive their nourishment from the exterior world, their different functions of digestion, assimilation, secretion, &c.; all of which will be duly noticed in their proper place.

CHAPTER I.

OF THE DIFFERENT FORCES CONCERNED IN ORGANIZED BEINGS.

All the knowledge derived by the intelligence of the exterior world, consists in an understanding of, 1, the *properties* of matter; 2, the unknown causes of its action, or *forces*; 3, the different forms which it may assume under the influence of molecular forces; and 4, the *offices* or *functions* performed by it, under its specific forms.

The human mind, from its very nature, cannot come into immediate, *direct* contact with the exterior world; all its information must necessarily be derived through the avenue of the special senses—hearing, sight, smell, taste, and touch. These sensibilities are placed intermediate between the mind and the external world. Hence a knowledge of the absolute, *essential* nature of matter can never be attained in the present state of existence,

inasmuch as the *properties* of matter alone can be appreciated by the senses. Sensibility is something quite distinct from the mind: it forms no part of the intellect, but is limited to a special nervous apparatus—special for each individual sense. This is proved by the fact that the sensibilities may continue in activity while the mind is suspended, and *vice versâ*; also, by the existence of sensibility in the very lowest order of animals, in which there is no evidence of the presence of intellect. Now the mind, though its *perceptive* faculties, is in direct communication with the different sensibilities, and is thus enabled to appreciate the different modifications produced upon them by the different properties of matter.

By a process of induction, the mind refers the various phenomena of the external world to certain *causes*; and if the recurrence of these phenomena be constant, under similar circumstances, the unknown cause is termed a *force*.

Force, then, is an abstract idea, expressive of the unknown cause of change of condition or state. Forces can only be known by the *phenomena* which they produce in matter. In mechanics, we speak of the forces of *gravitation* and *cohesion* as the unknown causes of attraction—the one between matter, the other between molecules. In thermotics we have to do with the force of *heat*; in optics with the force of *light*; in electricity and magnetism, with the forces known under these names. The same thing is true of *sound* and of *chemical affinity*. In all the above physical sciences, what are called their *laws*, are nothing more than *the conditions under which* their respective forces will act.

Conceding then the existence of the above special physical forces, governing inorganic matter, it becomes a matter of interesting inquiry how far the same forces and laws can be adduced to explain the phenomena of organized or living beings; or whether there is in them evidence of the existence of another force, totally distinct in its operations, and quite peculiar in its effects, to which the term *vital force* might appropriately be assigned. There is abundant proof to sustain both of these propositions:—namely, that many of the phenomena of living beings, are purely physical,

and are consequently, as such, controlled by the forces and laws of physics; again, that in living beings there are displayed certain *peculiar* phenomena, never found in inorganic matter, and existing only in animals and vegetables endowed with life, and expressed by the evolution of forms out of a formless material. It is to this latter force that it is proposed to restrict the term *vital* or *organic.*

To the vague and indefinite use of this term in Physiology, is to be traced much of the obscurity and error that have, more or less, been constantly prevalent. It has been too much the habit to confound together *all* the phenomena displayed by living beings, under the general term of "vital phenomena," because connected with life, and, because regarded as beyond the reach of human understanding, to ascribe them indiscriminately to a cause equally vague and unsatisfactory,—"vital action." Happily, however, these false views have begun to clear away before the light of a more exact and rigid mode of investigation; and the student of the present day is enabled satisfactorily to explain many of the apparently intricate phenomena of life, by a simple reference to the well-understood principles of the exact physical sciences.

Before proceeding to illustrate this position, it may be profitable briefly to allude to the doctrine of the *Correlation of Forces*, —a subject which is, at present, exciting considerable attention, both among physicists and physiologists. From the clearer insight obtained within late years into the nature of the phenomena of the physical sciences, the opinion has been gradually gaining ground, that the various physical forces, though apparently differing from each other, are in reality either modifications of one and the same force, or are correlative, or mutually convertible into each other.*

* Prof. Grove's treatise on the "Correlation of the Physical Forces," was the first published work upon this subject. The first edition appeared in 1843. It was followed in Germany by one from Mayer of Heilbronn, in 1845. Within the past year, Dr. Carpenter has investigated the subject, in an able communication to the Royal Society, entitled "On the Mutual Relations of the Vital and Physical Forces." Prior, however, to the appearance of any of the above treatises, Professor Jackson, of Philadelphia, had formally stated this doctrine, in an Introductory Lecture to his Course on the Institutes of Medicine, for the year 1837-8, as will be seen by the following extract:—"Physical phenomena, accord-

It was in the case of electricity and magnetism that this reciprocal relation, or "correlation," was first clearly understood. If an electric current be passed around a piece of soft iron, the latter becomes magnetic, and remains so as long as the current is circulating. On the other hand, a magnet in motion will develop electricity. We thus perceive that the two forces, electricity and magnetism, are mutually convertible, or *correlative*. The same is equally true of other forces; thus, heat may be developed from electricity, and *vice versâ*. In fact, no one of these forces can be called into action without, at the same time, exciting the other; thus, by retarding mechanical motion, as in *friction*, there are immediately developed heat, electricity, light, and magnetism. The correlation of heat and mechanic power is familiarly witnessed in the effects of steam (water converted into vapour by *heat*), as a motive power. The attempt has even been made to identify the forces of light, heat, and chemical affinity, by referring them simply to a difference in the velocity of the undulations of the same ether, believed to pervade all space. This idea was founded on the well-known fact, that while the greatest *illuminating* power of the solar spectrum is about its centre, the greatest *heating* effect is observed just beyond the red ray, where the undulations are least numerous; and the greatest *chemical* effect is produced just beyond the violet ray, where the undulations are most numerous.

The interesting question now arises,—is there any identity, or correlation between these physical forces, and those observed in organized or living beings? In order properly to reply, it will be necessary to take a survey of all the phenomena of living beings, and subject them to a rigid analysis. It will then be found that many of these phenomena—usually termed *vital*, because connected with vitality—are governed by laws precisely similar to those which control organic matter; while a few only exhibit evidence of the influence of a law *peculiar* to living beings, and to

ing to the class they belong to, are referred to a few simple laws, as gravity, caloric, affinity, galvanism, electricity, magnetism, all of which, it can now be scarcely doubted, are modifications of one great law or force."

which exclusively, we should properly restrict the term *law of vitality*. We may illustrate this by a few familiar examples. The transformation of the crude albumen into the protoplasmas, or immediate organizable materials for the structure, is an undoubted chemical action; it requires a temperature of about 98°. The circulation of the blood by means of the propelling power of the heart, aided by the elasticity of the arteries, is a purely physical phenomenon, governed by the laws of hydraulics. Respiration is a combination of physical and chemical actions,—the former controlling the respiratory movements of the chest, and the interchange of gases by endosmose, through the air-cells of the lungs; the latter affecting the condition of the blood circulating through the lungs. Digestion is a function partly mechanical, so far as relates to the peristaltic movements of the stomach and bowels; and partly chemical, so far as concerns the different chemical changes produced in the ingesta. Muscular motion, including locomotion, is essentially a mechanical action; the whole muscular apparatus being, in fact, the mechanical power employed by the economy for the working of most of its functions, under the dynamic influence of the nerve-centres. Secretion is a function partially, at least, under the influence of the physical law of endosmose, and of chemical action. Absorption belongs wholly to the domain of physics; Calorification, solely to that of chemistry. Finally, the apparatuses of vision, hearing, and the voice, are all constructed in the most exact conformity with the physical laws of optics, acoustics, and phonation.

Thus we perceive that nearly all the so-called phenomena of vitality—digestion, respiration, circulation, absorption, muscularity, secretion, calorification, &c., are controlled by forces *identical* with those which govern inorganic matter; and these forces, although limited in their operation in living beings, and subserving the one great end of the conservation of the being, are none the less *physical* because connected with *living* actions.

Let us now examine the question whether the *vital* or *organic force*, in its strictest sense, has any identity, or correlation with the above-named physical forces. It will be remembered that we

restrict the use of the term to express a force exhibited *exclusively* by living beings. Now, the only phenomena *peculiar* to living beings are the nervous force controlling muscular contraction, and the power of evolving special, typical forms out of a formless material.

As regards the *nerve-force,* it is obvious that it cannot fall within the above definition of organic force, since it is not found in vegetables, nor is it indispensable even to animal existence; the organic functions of even the higher animals being only indirectly under its control. Nervous force is certainly correlative with galvanism or electricity; but it is altogether distinct from the operations of mind, as displayed in the phenomena of the intellect, and moral faculties. The nerve-force is only the dynamic excitor of muscular contraction, and has acquired the distinction of a vital force from its necessity as an excitor of the muscular actions of respiration in man and the higher animals.

It is then to "the evolution of forms out of a formless material," that we are to confine our meaning of the term organic or vital force. This force must be present in every organized being, and participate in every life-action.

The great variety of forms which is presented in an organized being, owes its origin to one common material, termed *plasma, blastema, cytoblastema,* &c.; these forms, moreover, owe their constant maintenance and renewal to this same material, which, chemically, is albumen. But, for the production of each special form, this common plasma must first become special, or *protoplasma;* thus, it is one kind for muscles, another for nerve-substance, another for bone, &c. As soon as speciality is given to the organizable material,—indeed simultaneously with it in the actual life-actions,—special forms are developed, through the controlling, mysterious agency of the *germ-power* which is manifested wherever organization is going on.

As a special form is insured by a special material, so *speciality of function* is the result of a special form. Indeed, as Müller observes, material, form, and function must always coexist; they cannot be separated. In this manner it is that every organ of

the body has its specific function. Every living cell is, in fact, a specific organism, performing certain specific actions; the vegetable cell, for example, under the agency of the sun's rays, decomposes carbonic acid, and the animal cells elaborate the various secretions of the body.

From a consideration of what has just been said, it will be apparent that, though the production of special materials, or protoplasmas, out of one common material, and the evolution of special forms are consentaneous acts, they are, nevertheless, quite distinct. The first is really chemical; it comprises the transformation of the crude material of the egg—albumen—into fibrin, gelatin, neurine, and the various other proximate elements of the tissues. But it is not *common* chemical action; it is *organico-chemical,* since it is controlled by the germ-force; without this latter agency, the crude material, instead of undergoing the higher developments just mentioned, would suffer ordinary chemical putrefaction, as is witnessed in an unfecundated egg when exposed to the proper temperature for incubation, and to atmospheric air; decomposition is the only result. Thus far, then, we may admit the correlation between the organic force and chemical action and heat. But, certainly, there is no identity between that higher power of the organic force, which determines the production of forms after a special type, and any of the ordinary physical forces, heat, light, electricity, &c.—they are entirely distinct, and are only *correlative,* so far as has been just explained.

It will here be proper to observe that the above views, which are substantially the same as those taught by Prof. Jackson, in his public lectures, do not altogether accord with the opinion of Dr. Carpenter, as exhibited in the last edition of his works on Physiology, and in his paper on "The Mutual Relations of the Vital and Physical Forces," already alluded to. Dr. Carpenter's idea is that, as in Physics, one force is converted into another through the medium of a certain form of matter, or *material substratum,*—as when electricity is converted into magnetism through iron, or heat into electricity through a combination of bismuth and antimony, so "all the truly *vital* phenomena, however diver-

sified, are but results of the operation of one and the same force, whose particular manifestations are determined by the nature of the material substratum through which it acts; the same fundamental agency producing simple *growth* in one case, *transformation* in another, *multiplication* in a third, *mechanical movement* in a fourth, whilst in a fifth it developes *nervous power*, which may itself operate in a variety of different modes."

Under this view, it will be perceived that the ordinary physical forces, light, heat, electricity, &c., are regarded as capable of being converted into vital force, by acting upon organic matter under certain conditions. It does not recognise any *peculiar* vital force, characterized by the "evolution of forms from a formless material."

The vital or organic force acts upon the amorphous organic mass, modifying it so as to produce secondary forms, and develope it into a new structure. As will hereafter be shown, all organized beings, from the lowest to the highest, have their origin in cells, or rather in germs, out of which the cells are formed. These cells *grow* by appropriating the surrounding materials; thus the vegetable-cell has the power of decomposing water, carbonic acid, and ammonia, under the influence of the sun's light, and of combining the carbon, oxygen, and hydrogen, so as to form the gummy or starchy product, which serves as the pabulum of the vegetable tissues. It is possible that thus far the act may be simply chemical, resulting from what is termed the action of *catalysis*, in which one body exerts an influence over two other bodies, so as to occasion their union or separation, without itself undergoing any change. Thus, it has been conjectured that the germinal molecule may exert this kind of an influence over the elements of the water and carbonic acid, with which it is in contact. The *animal* cell does not possess this power; it can only modify, or work up the material submitted to it.

The *dynamic forces* are totally distinct from the vital. They are connected with the excito-motor nervous system, and are displayed by the muscles as their appropriate agents. As many important functions of the economy are performed through the

agency of the dynamic forces, they will require a separate notice in a subsequent part of this work, (Part IV.)

CHAPTER II.

CONDITIONS FOR THE DISPLAY OF THE VITAL FORCE.

The organic or vital force is not only the cause of all original formative action in the development of the germ, it also presides over its whole future growth, being inseparably connected with each of the successive stages of the process of nutrition. It is not, however, self-acting; but is dependent upon certain exterior agents for power to develope it into activity. A seed, for instance, although possessing a dormant vitality, or in other words *alive*, will never germinate, unless exposed to a proper heat, to moisture, oxygen, and probably also light. Some of these conditions required for the display of vital force are so indispensable, that they have received the name of *the essential conditions*, or *laws of life;* they are, 1. The presence of a germ; 2. A plastic or organizable material,—albumen for animals, dextrine for vegetables; 3. A certain amount of caloric, differing for different genera of plants and animals; for man, it is from 98° to 100°; 4. Oxygen, in the proportion in which it exists in the atmosphere; 5. Moisture;—a certain amount of water is requisite to give due fluidity to the various matters for nutrition and secretion. To these may be added, as of less essential importance, Light, which is indispensable to the functions of vegetables, though not to the evolution of their forms.

Since the whole of organic life is but a repetition of its first acts, it follows that the first five of the above conditions are always essential. If any one of them be absent for a length of time,

disease must be the result; and if all of them be absent, death must inevitably follow.

We will now examine into these "essential conditions of life" more in detail.

SECTION I.

OF THE GERM, AS AN ESSENTIAL CONDITION OF LIFE.

THE *germ* is perhaps the most important of all the indispensable conditions of life, since in it resides that wonderful power of developing special forms according to some particular type. The germ-force may consequently be regarded as identical with the vital or organic force already described. If it be absent in the process of organization, although all the other essential conditions of vitality be present, such as a healthy plasma, oxygen, and a normal temperature, no form can be evolved, but the result will be simply the ordinary play of the chemical affinities, terminating in decomposition. This is well illustrated in an egg which has been laid before impregnation by the male: if this be submitted to the temperature proper for incubation, it only undergoes putrefaction: wanting merely the *germ-force*, its otherwise healthy material is incapable of taking on organization.

At its commencement, the germ is but a microscopic point, scarcely visible by the highest magnifier. It is always the result of the union of two distinct cells, the ovo-cell and the germ-cell; and it is moreover transmitted to every part of the organism, by being split up or divided by the process termed *segmentation*, by which it first divides into two, then each one of these again into two; and so on, constantly doubling, until the whole is broken up into countless granules, *each one of which* must of course be endowed with all the qualities of the original germ, and thus becomes, in point of fact, a true germ or *nucleus*. In the eggs of birds and reptiles, it is only the cicatricula (which corresponds with the

ovum of mammalia) that undergoes this process of segmentation; the yolk merely serves as a store of nourishment for the embryo. The name of *mulberry mass* is sometimes given to the aggregated mass thus produced. Each little granule augments by assimilation from the surrounding materials, and shortly becomes enveloped by an organic membrane, by which it is constituted *a cell;* within which the germ, or nucleus is contained.

Each cell thus formed is an independent living organism, performing its allotted functions, and living through its allotted space of life. Many animals and vegetables never advance farther than this point of development; as is witnessed in the monads, and in the *Protococcus nivalis*, or *red snow* of the Arctic regions.

The fact that the germ is always the offspring of two distinct parents, will account for the complexity of its composition. In the very earliest period of its development, when the *germinal membrane* begins to form upon the germinal mass, we find it consisting of two distinct layers; the inner, or mucous one being destined to give origin to all the organs of organic life—as the alimentary, respiratory, and circulatory organs; while the outer layer developes the organs of animal life—as the nervous, muscular, and osseous systems.

What are termed *nuclei of cells* or *tissue-germs*, are the lineal descendants of the primordial or original ovo-germ: they are to the respective tissues what the ovo-germ is to the whole being. As they are endowed with germ-force, they are the instruments for manufacturing the various protoplasms; hence any cause producing an arrest in the development of the tissue-germs of any particular tissue will result in atrophy of that tissue; whilst hypertrophy would be the result of their excessive production. They are the agents by which all the different organs are maintained in their normal condition, since they replace what is constantly being lost by ordinary disintegration. Farther, they are the instruments by which alone injuries are repaired, and the loss of substance supplied, provided the structure required be of a simple homogeneous character, as the areolar tissue; or even an entire limb of one of the lowest order of animals. In tissues of

greater complexity, as the nervous, and muscular, perfect reparation becomes much more difficult, if not impossible. The cause of this difficulty is by Mr. Owen ascribed to "an exhaustion of the germ-force in the original production of these tissues, and that, consequently, their loss of substance cannot be supplied." Now this can hardly be the true explanation, since, if the germ-force were really *exhausted* at the first, the *forms* of the structures could not be constantly maintained throughout life. It may rather be ascribed to the impossibility of keeping the parts in that condition of absolute repose which they enjoyed at their first formation. As an evidence of this, we occasionally witness recovery from paralysis by perfect rest for several years.

In some of the complex tissues we find two distinct sets of actions, the results of the germ-force. In the epithelial tissues, for example, the *germinal centres* of the basement-membrane (or the tissue-germs) have for their office simply to constantly develope the chemical, or epithelial cells; whilst these latter possess no reproductive power, but are destined simply to *secrete* from the blood, in the performance of which they die, and are cast off. The same is true of muscular structure; the cells destined to produce muscular contraction undergo no histological change, and are destitute of the power of self-production, their constant destruction being supplied by the nuclei of the sarcolemma, which, on the other hand, possess no contractile power. It can now readily be understood how difficult it would be to repair any considerable loss of such complex structures, on account of the destruction of the tissue-germs—the only instruments for the repair. In such cases, a fibrous matter is usually supplied, as the bond of union.

As in the germ resides the force which developes the whole future being, so through it, also, are transmitted all the peculiarities of hereditary descent, whether of a healthy or diseased character. The latter are especially witnessed in scrofulosis, tuberculosis, and idiocy.

SECTION II.

OF THE PLASMA OR ORGANIZABLE MATERIAL, AS AN ESSENTIAL CONDITION OF LIFE.

THE second indispensable condition of life is the presence of a proper organizable material, or *plasma,* on which the organic force may act, and out of it construct the different tissues and organs of the body. In vegetables this material consists of *dextrine;* in the egg it is contained in the yolk, which consists chiefly of albumen; in animals, and in man it is found in the blood. The liquor sanguinis may in fact be regarded as a concentrated solution of all the materials necessary for the construction of the organs and tissues, as well as for the secretions. The corpuscles of the blood are not directly concerned in producing the plasma; though indirectly they act by transforming the crude albumen into fibrin, a function assigned by most physiologists to the *red corpuscles;* the latter are intimately connected with the nerve-forces.

The plasma contains albumen and fibrin; but neither of these proximate constituents, *as such,* can be said to enter into the composition of any organ; even the fibrin of muscles, according to Liebig, differs from that found in the blood. Moreover, neither gelatine nor neurine have ever been found in the blood. Hence, it appears that all the immediate materials for the formation of tissues—or the various protoplasms—do not pre-exist in the blood, but are evolved from it by the agency of the germ-force. This evolution of the protoplasms occurs simultaneously with the evolution of the various forms; and this double process is incessantly taking place, to compensate for the incessant disintegration of the tissues, in the acts of life.

The constant supply of this reparative material is, as we have seen, derived from the blood, which in its turn is supplied from the food taken in. Now, the daily amount of the waste or disintegration of the azotized tissues, in an adult man, is from two to three ounces; this must all be supplied from the food through the blood, since

animals are unable to manufacture a particle of azotized matter; this is the exclusive province of vegetable cells: animals can only modify it, or cause it to assume different forms. The greater part of man's food—nearly seven-eighths—as presented to us by nature, contains no nitrogen, and is destined to support animal temperature, by undergoing oxidation, or slow combustion, in the body. From this abundant provision for the maintenance of animal heat, we may infer its great importance to the economy; it is essential, as we shall hereafter find, for the conversion of the common plasma into the various protoplasmata.

The food as swallowed into the stomach is not fit for the purposes of nutrition without first undergoing the process of *digestion*, by which all the albuminous principles are converted into a common soluble matter, named by Mialhe *albuminose*. From its solubility and miscibility with the blood, this matter is capable of being imbibed immediately into the blood-vessels of the stomach; and in this way probably it is that some of the azotized portion of food is disposed of.

Plasma may hence be considered as the transitional stage between crude food and organized structure. It has already been pointed out that animals derive all their azotized food from vegetables, since they themselves create nothing; farther, the matter thus presented for food requires that its ultimate elements, carbon, oxygen, hydrogen, and nitrogen, should be in the *exact proportion* of those of albumen; otherwise, even though all the elements were present, the substance could not be used for food, as is seen in the case of quinia, morphia, caffein, &c.; these latter are powerful medicinal agents, acting on the nervous centres, but are quite destitute of nutritive qualities. We may infer from these facts the great importance of a due attention to dietetics. For the preservation of health there must be from two to three ounces of nutritious (albuminous) materials, per diem, in the food of adults; yet this is very often neglected, especially by those of sedentary habits, who are apt to substitute for it the inordinate use of coffee and tea, and thus bring on the effects of inanition.

As the food which furnishes the plasma is derived from the ex-

terior world, it is liable to defect in several ways; as, first, from an absolute deficiency of it, arising from the use of innutritious or otherwise improper food, from chronic diseases of the digestive organs, or from marasmus; secondly, from the existence of certain constitutional disease, as tubercle, scrofula, cancer, &c.; thirdly, by absorption of noxious matters from without, as the various contagious viruses, miasmata, typhoid matter, &c.; these all acting as ferments in the blood, must transform the true plasma into their own peculiar matter; and the efforts made by the system to throw off this morbific matter, constitute *disease;* fourthly, by the introduction of certain kinds of animal virus into the blood, as from the bite of a rattlesnake, viper, &c.; fifthly, by the generation of a poison in the blood, as is witnessed in the blood of animals overdriven in hot weather; the blood of such animals if inoculated into a healthy animal would be likely to produce death; sixthly, the blood may be poisoned, and the plasma of course deteriorated, by the retention of noxious matters designed to be removed by the excretions; thus the retention in the blood of urea, uric acid, bilin, sugar, &c., is often the cause of disease. Some of the substances found in the blood are undergoing constant decomposition in the normal state; as lactic acid and the lactates, their carbon and hydrogen serving as fuel for combustion to produce animal heat; they may occasionally, however, accumulate in the blood.

SECTION III.

OF OXYGEN, AS AN ESSENTIAL CONDITION OF LIFE.

The presence of this gas throughout nature is indispensable. For living animals and plants the proportion of it required is just that in which it exists in the air.

The composition of the atmosphere is by weight, seventy-seven parts of nitrogen, and twenty-three of oxygen; by volume, about

eighty parts of nitrogen and twenty of oxygen. There are also from four to six parts of carbonic acid in every thousand of air, together with a variable amount of moisture, and a minute quantity of ammonia, especially after a thunder-storm.

A most abundant provision is made for the supply of every living being with this most necessary element of life. The whole surface of the globe is covered over with a vast aerial ocean, which exerts upon it a pressure of nearly fifteen pounds to every square inch, but diminishing in density in proportion to the elevation from the surface. It is liable to contamination from various sources, as respiration, combustion, putrefaction, fermentation, and various sorts of exhalations; nevertheless, the accumulation of any noxious matters in a circumscribed portion of air is prevented by the "laws of diffusion" of gases, as shown by Mr. Graham; the diffusibility of any two gases being "inversely to the square root of their density." The air of cities is always more impure than that of the open country; this is the cause of the languor and depressing sensations experienced in towns during hot weather, which is not the case in the country, although the temperature may be quite as high. Hence, too, the greater mortality of large cities, it being from thirty to fifty per cent. more, for the same disease, in the city than in the country; besides the number of cases of the same disease being about forty-five per cent. more in the cities, than in an equally numerous rural population.

The whole quantity of air consumed by a healthy adult man in twenty-four hours amounts to about 266 cubic feet; of this, twenty-five ounces (Liebig says thirty-seven) consist of oxygen. The amount of solid carbon eliminated from the body in the form of carbonic acid amounts, according to Liebig, to 13·9 ounces; but this is by many considered too high; they estimate that ten or eleven ounces more nearly express the true amount of carbon excreted per diem, by both the lungs and skin.

There is a mutual relation between the amount of oxygen inhaled and that of carbonic acid expired; the latter being regulated by the former. From ten to fifteen cubic feet of carbonic acid

are exhaled by a healthy adult man in twenty-four hours; now, if the quantity of oxygen inhaled be diminished from any cause, whether by contamination or rarefaction, the effect will be the retention of the carbonic acid in the blood, producing injurious results, and even asphyxia, when it reaches a certain amount. In these cases the danger is vastly greater if the accumulation of the carbonic acid in the air is at the expense of the oxygen, than if there was merely a *surplus* of carbonic acid, the oxygen remaining undiminished. One per cent. of carbonic acid in the atmosphere is sufficient to produce unpleasant results, such as headache, lassitude, &c.; and twelve per cent. is sufficient to cause death.

Oxygen is the great decomposing agent in the animal economy. Inhaled, in the act of respiration, into the lungs, it passes into the circulation; and in the capillary region it enters into combination with the various elements of the tissues, thus causing their disintegration, and producing the different effete matters thrown off from the economy. Especially, is the oxygen thus inhaled disposed to unite with carbon and hydrogen, giving rise to carbonic acid and watery vapour, and producing, as a result, a certain amount of heat in the system, known as *animal temperature*. The degree of heat evolved by this species of slow combustion is precisely equal to that produced by the rapid combustion of the same quantity of hydro-carbon out of the body. Heat is also generated in the germination of seeds (as witnessed in the malting of barley), and in the flowering of plants; oxygen being essential to both processes,—a species of slow combustion or oxidation taking place in both.

The great importance of oxygen to the animal economy is too frequently lost sight of in the construction of buildings for the accommodation of large numbers of persons. When it is remembered that every adult vitiates 250 to 300 cubic feet of air in respiration, in twenty-four hours, and that this quantity must be actually renewed, the importance of proper *ventilation* will be rightly appreciated. But it is not only the carbonic acid thrown off by the lungs that contaminates the air, but this is still farther aided by the animal exhalations which are constantly passing off

from the body. These two causes combined have been the prolific source of typhus fever, and hospital gangrene. Another result of the vitiation of the atmosphere by these causes is the increase thereby given both to the number of cases, and the mortality of any epidemic; it is sure to be particularly violent in the crowded, filthy courts and alleys of cities, because, in such situations, the forces of life are sooner exhausted.

Atmospheric variations, though not generally noticed by persons in vigorous health, are very sensibly felt by the invalid. The different effects experienced by the latter in breathing the more rarefied air of the mountains, and the comparatively denser atmosphere of the sea-side, is a proof of this. Chronic diseases are generally ameliorated when the barometer is high, indicating fair weather, and a heavy atmosphere.

Under certain conditions, the atmosphere exhibits evidence of the existence of a peculiar substance called *ozone*. Various opinions are held in reference to this principle; some consider it to be a new element; others, as Berzelius and Faraday, regard it as only an allatropic condition of oxygen; by others, again, it is considered a peroxide of hydrogen, expressed by HO_4, or HO_5.

Ozone is also perceived in the spark procured from the electric machine, and when phosphorus is in contact with moist air. Its properties are quite peculiar: it is the most powerful oxidizing body known; polished silver becoming speedily tarnished on exposure to it. To its oxidizing agency may be ascribed the formation of the nitrates and sulphates in nature. It is the most powerful bleaching agent known, the bleaching property attributed usually to the sun's rays being, in reality, due to it. Through the same oxidizing agency, it is a powerful disinfectant. In this way it proves useful in the atmosphere of cities, and for this reason it cannot be discovered in such an atmosphere, because it has been consumed in combining with the noxious emanations.

It is most abundant in winter, when the ground is covered with snow; also in the open country, especially on the sea-side; also, immediately after a thunder-storm.

Its presence can be detected by moistening a piece of paper

with a solution of ten grains of starch and one grain of iodide of potassium in a hundred grains of water; this paper is dried, and when wanted for use, is to be moistened in water, and then exposed to the air; the depth of blue colour is regarded as indicative of the amount of ozone present.

SECTION IV.

OF HEAT, AS AN INDISPENSABLE CONDITION OF LIFE.

THE great importance of *heat* to all living beings is exhibited in the abundant provision made for it by nature; its amount being always in the ratio of the vital processes both of vegetables and animals.

Its influence upon vegetation is witnessed on a large scale, by comparing the barrenness of the polar regions with the luxurious growth of the tropics; and also in the alternations of winter and summer in temperate climates. Vegetables appear more affected by a withdrawal of heat than animals, because they have no power of generating caloric for themselves, excepting at certain periods, and in certain organs which do not impart it to the rest of the structure. The different genera and species of vegetables are endowed with different powers of enduring heat and cold. Accordingly we find peculiar races adapted to each of the varieties of climate upon the earth's surface; and when any one of these is removed from its own appropriate temperature, it either perishes, or its nutritive processes are materially interfered with.

The plants capable of enduring the *lowest* temperature are the Cryptogamic tribes, as ferns, mosses, lichens, &c.; and accordingly, the proportion of these to the Phanerogamia, or flowering plants increases as we advance from the equator towards the poles. Among flowering plants, moreover, the greatest endurance of cold is found in those which most nearly resemble the Cryptogamia in development,—as the grasses, rushes, and sedges; hence these

are found to constitute about *one-eleventh* of the whole of the flowering plants in the tropics, *one-fourth* in the temperate zones, and *one-third* in the polar regions. The ratio of the Gymnospermic group of exogens—as the fir and pine—increases in like manner.

The temperature of a place is not only regulated by its distance from the equator, but also by its elevation above the sea. The *snow-line*, or the region of perpetual snow on mountains, will of course vary according to the distance from the equator; thus, under the equator, it is from 15 to 16,000 feet above the level of the sea; on the Swiss Alps, about 8000 feet. The elevation, however, is very much affected by local circumstances, as the proximity to a large expanse of sea or land; the former condition rendering the climate much colder at equal elevations.

The evaporation of moisture which is constantly taking place from the surface of plants enables them to resist, to a great extent, the consequences of excessive heat. This ability, however, depends upon their receiving a due supply of water. If this supply be adequate to the demand, all the vital operations will be stimulated by the heat to increased energy; and unusual luxuriance of growth may result. But if the supply of water be inadequate, then the plant either withers and dies, or else its tissues become dense and contracted; as is seen in the stunted shrubs of the sandy deserts of the East. The highest temperature observed by Humboldt in the soil of tropical climates was from 126° to 140°.

The influence of a very low temperature is well known to be fatal to most kinds of vegetation; although there may frequently be a complete cessation of the vital processes, or in other words, they may be *dormant*, without the vitality being lost,—a rise of temperature being only requisite, again to call them into action.

It is doubtless through chemical or physical agency that cold proves destructive to vegetation, causing congelation in the fluids, and rupture of the cells, by the expansion produced in freezing. Also, there may be a separation caused between the constituent parts of the juices of the plant by the act of freezing, which may be incompatible with its functions. Hence we find that the succulent plants, which abound in fluids, are most injured by cold;

and that the young shoots are more affected than the branches or trunk. Again, the viscid nature of the juices of a plant may enable it to resist the congealing influence of cold; hence the Pines, and other resinous trees are well adapted to extremely low temperatures. It also appears that *seeds* are capable of enduring an exposure, without injury, to a temperature which would be entirely fatal to growing plants of the same species; this arises, no doubt, from the closeness of their texture, and the minute quantity of moisture they contain.

The influence of heat upon animals is of equal importance with its effects on vegetables; though it is exerted in a very different manner, from the fact that most animals have the power of generating heat within themselves, totally independent of the external temperature. Still, it is very easy to show that if the conditions necessary for the production of animal heat be interfered with, the animal will as certainly suffer, or even perish, as the vegetable.

Animal temperature is the standard by which we judge of the internal organic actions of animals. Like ordinary heat, it is the result of a process of combustion, or oxidation; the *fuel* consumed being chiefly the carbon and hydrogen of the food. From thirteen to fourteen ounces of pure carbon, per diem, are required in the food of an adult. This will be more fully explained hereafter. (Part. IV.)

Heat subserves two very important purposes in the animal economy; *first*, it is indispensable for the production of the various protoplasmata out of the common plasma, and likewise for the evolution of forms, and *secondly*, it developes mechanic power by being converted into the nerve motor force, through the medium of the nerve-centres. The correlation of heat and mechanic force has already been pointed out. M. Joule ascertained that the degree of heat required to raise one gramme (15 grs.) of water, one degree is equivalent to the mechanic force necessary to elevate a weight of 432 grammes (13½ oz.), one metre.

The *manner* in which animal heat is produced will be spoken of hereafter; it is sufficient here to remark that this power is not equally possessed by different animals; a circumstance which has

occasioned the division of them into the two classes of *warm-blooded* and *cold-blooded*.

It is from their different capacities for generating heat, that animals are adapted to varieties of climate; those which possess this capacity to the greatest degree being always found in the coldest countries; those, on the other hand, which have the capacity least, being placed in tropical countries. Such animals cannot bear a removal to different climates, unless the temperature be artificially regulated, so as to resemble that to which they were accustomed. The human race is capable of enduring variations of climate much better than animals; though even man requires time to become accustomed to changes of this sort.

It has been satisfactorily demonstrated by the recent experiments of Chossat, that the reduction of the temperature is the *immediate* cause of death, in starvation. This, he proved by a series of experiments upon birds; and he found that the reduction of temperature was quite regular from day to day, so long as any fat remained upon the animal; but as soon as this was exhausted, the temperature rapidly fell, and the animal soon died. But if, at this point, it was subjected to *artificial* heat, it was immediately resuscitated; its own temperature rose, and if nourishment was given it, a complete restoration to health ensued. This affords a valuable practical hint in the treatment of diseases of exhaustion, in which the great lowering of the temperature is the *immediate* cause of death. The proper treatment in such cases, is to sustain the temperature of the body, both by the application of external heat, and the judicious administration of *alcohol*, which, from its chemical composition, is admirably adapted to furnish materials for the process of internal combustion—the usual source of animal caloric.

Among the warm-blooded classes of animals, there are some which possess the peculiar property of losing the greater part of their power of generating heat at stated times; during which their temperature is reduced very nearly to that of the surrounding medium, and their vital functions become nearly, if not entirely, dormant. The term *hybernating* is applied to such animals; and

this condition appears to be as natural to them as sleep, and as periodical in its return.

An animal in the state of hybernation closely resembles a *cold-blooded* animal, so far as regards its dependence for heat upon the surrounding medium; but it differs from the latter in the fact of not retaining its functional activity at a reduction of its temperature, which is entirely natural to the other.

The different stages of Insect life appear to be very considerably influenced by temperature. In the *larva* state of insects, the temperature is but very slightly elevated above the external air. In the *pupa* or *chrysalis* state, which is one of perfect rest, the temperature is scarcely above that of the atmosphere. But in the fully developed insect, we find a considerable elevation of temperature attained, varying, however, in different species. Now, the development of the larva from the egg may be either hastened or retarded, simply by raising or lowering the temperature; and the development of the insect from the *pupa* state may be influenced just in the same manner.

As respects the *degree* of heat which animals can sustain compatible with life, we find a difference among the different tribes. The higher classes and man seem capable of great endurance. Thus, instances are recorded of individuals sustaining a temperature of 350° to 500° for a short time, with proper precautions. In such cases, however, the *real* heat of the body is but very little elevated; the copious evaporation from the surface having a tendency to lower the temperature. But if this evaporation be prevented, either by saturating the air with moisture, or by not supplying a sufficient quantity of fluid within, the heat of the body then rises, and very shortly death ensues. By experiment, it has been found that an actual rise in the temperature of 9° to 13° above the normal standard, is sufficient to destroy life.

As regards the greatest reduction of temperature consistent with animal life, we have already seen that there is a great difference among the various species. As an extreme case, we may cite an instance that occurred in one of the Arctic voyages, of several caterpillars having been exposed to a temperature of 40°

below zero, and so completely frozen, that they resembled lumps of ice; yet, when thawed, they resumed all their movements. One of them was frozen and thawed *four* times, and afterwards underwent the usual transformation into a chrysalis and moth. In the same way, fishes that have been completely frozen in ice, so as to be brittle, have revived on being thawed. Spallanzani kept frogs and snakes in an ice-house for three years; at the end of which they revived, on being warmed.

SECTION V.

OF LIGHT, AS A CONDITION OF VITAL ACTION.

THE importance of this agent in the organic world is not, generally speaking, properly estimated. We may form some idea of its value from the fact, that it is only by its influence that vegetables exert the wonderful process of converting inorganic matter into an organic compound. The simplest example of this is to be seen in the formation of the "green matter" upon the surface of standing water, or upon damp walls or rocks, under the action of the sun's light. This matter is now known to be a *plant*, consisting of cells in different stages of development. These cells are evidently produced from pre-existing germs, and not from a direct combination of the inorganic elements; as is proved by entirely freeing the water, and also the air in contact with it, from all organic matters; when this is done, the strongest light produces no effect upon the water.

That light, and not *heat*, is the chief cause of the change, is proved by the fact that no degree of heat is sufficient, if light be absent; but a very moderate amount of heat will suffice, if light be present.

Prof. Draper has clearly proved by experiments upon the different colours of the solar spectrum, that this force resides most

in the yellow ray, or that possessed of the greatest *illuminating* power.

The changes which take place when the above conditions are present, consist in the decomposition of the carbonic acid by the cells of the plant, the setting free of oxygen, and the appropriating the carbon; which last, when united to the elements of water, constitutes the chief part of the vegetable fabric. It is not quite certain how far the agency of light is necessary in the absorption of *nitrogen*, which is requisite for the formation of the azotized principles of plants.

Now, precisely the same series of changes takes place in the cells of the most complex plants; their structure is increased, or they *grow*, by this same power of decomposing the carbonic acid through the agency of light: this may be easily shown by allowing seeds to germinate in the dark; the young plants will live for a short time, but they do not increase in *weight*, though they do in *bulk*, in consequence of absorbing water. It is only the green surfaces of the leaves, or young shoots of plants, which possess this decomposing power; so that, when these parts decay or fall off, this power ceases also, and a converse operation goes on, namely, the absorption of oxygen, and the giving out of carbonic acid. Thus, the leaves act as the *digestive* organs of the plants, preparing products which are conveyed to all parts of their structure, by means of the descending sap, so as to become the materials for their nutrition.

There is another process quite distinct from this, which is constantly going on in plants—their *respiration*. This is essentially the same as the respiration of animals; oxygen being absorbed, and carbonic acid being given out. It is carried on chiefly by the dark surfaces of the plant, and not at all by the green leaves. During daylight, it is not obvious in a healthy plant, on account of the preponderance of the other function; but it is manifest in the dark, and when the plant becomes unhealthy, or when about losing its leaves.

It is generally observed that the vegetation of places, where there is a large amount of carbonic acid present, is unusually

luxuriant, provided the sun's light be unclouded; and there is strong reason for believing, that in the earlier epochs of the earth's history, the atmosphere contained much more carbonic acid than it does at present; and, in this way, we may account for the enormous fossil vegetable remains, for instance, of ferns which attained the size of perfect trees. In the same manner we may account for the formation of the vast beds of coal, a substance exclusively of vegetable origin.

The influence of light is also felt upon the *exhaling* power of the leaves. Most of the watery portions of the ascending sap are thrown off by the leaves, by a process of exhalation; this process goes on rapidly under the action of light, which stimulates the *stomata*, or little orifices in the cuticle of the leaves, to expand so as to allow the fluid to pass out.

During the early stages of the *germination* of plants, the presence of light is rather injurious than otherwise. This arises from the fact that, at this time, a converse change from the one above alluded to takes place; carbonic acid is given out, and oxygen absorbed. But as soon as the cotyledons are unfolded, immediately the process of *fixing* carbon is commenced. All plants do not require the same amount of light for their development; those which have thick and succulent parts generally need most, and hence grow in the most open and exposed situations. The cryptogamous plants require less, and are, therefore, met with in dark and sheltered places.

The only exception to the general law, that growing plants rerequire the stimulus of light, is in the case of the fungi; and this may be easily explained, by the fact that their food is supplied to them by the decomposition of the substances in which they grow, and not from the atmosphere; and the rapidity of their interstitial changes involves a high amount of respiration, by which carbonic acid is eliminated, and oxygen absorbed, just as in the germinating seed. The part performed by the fungi, and many of the moulds which attach themselves to decaying vegetable and animal matter, and feed upon their materials, is highly important in reference to the purification of the atmosphere;

hence they have been, not inappropriately, named *Nature's scavengers.* We thus observe a beautiful balance throughout Nature between vegetables and animals; the one appropriating what the other gives out.

The organic functions of animals do not seem to be so much under the influence of light as those of vegetables; because animals do not perform the same acts of combination from the inorganic kingdom, but make use of the products already prepared for them by plants. Hence the necessity for light is not so great. Still there is every reason to believe, that the *colours* of animals are very considerably influenced by their degree of exposure to light. In this way we may account for the dark skins of the inhabitants of the tropics—the *permanency* of the hue being produced by the continued action of the stimulus, from one generation to another. In the same way, the brilliancy of colours seen in most of the birds and insects, as well as of the foliage and fruit, of tropical climates, appears owing to the brightness of the light; for it is known that if birds of a brilliant plumage be reared by artificial temperature in colder climates, they never fully acquire the same bright colours.

The *development* of animals is also much influenced by the amount of light to which they are exposed; this is particularly the case with the lowest animalcules, as those generated in water containing organic remains; their number surprisingly increasing when the light is bright. Dr. Edwards has shown that the development of frogs from the tadpole state may be entirely arrested, if the animals be secluded from the light. There is no question that the full development of the human race is greatly influenced by light. Thus we may witness the injurious effects resulting to the inhabitants of large manufacturing towns, where whole families are often pent up in cellars, or in narrow alleys. Here, to be sure, the individuals suffer from want of ventilation, and from bad diet; but we have only to contrast the pale sickly skins of such persons, and more particularly of those who pass most of their lives in deep mines, where they become completely *etiolated*

or blanched, with the ruddy complexion of the sailor or farmer, to perceive the influence of light.

Among the "conditions of life" it is often customary to consider *Moisture;* this has already been incidentally alluded to under the head of *the plasma;* and it will be treated of more in detail hereafter under the head of the Inorganic Constituents of the Body. A few remarks may not, however, be out of place in this connexion.

SECTION VI.

OF MOISTURE, AS A CONDITION OF VITAL ACTION.

THE necessity of water as a solvent has already been alluded to. It is equally essential to both vital and chemical action. It is impossible that nutrition should take place without the aliment being first reduced to the fluid state, so as to be absorbed into the system; and again, the different solid matters of the secretions and the excretions must become fluid before they can be eliminated; and these changes are accomplished solely by the agency of *water*.

The importance of the fluids may be inferred from the great proportion they bear to the solids, in organized beings. Thus the amount of water entering into the composition of man, amounts to ninety per cent. Again, the fluids invariably precede the solids in their formation, which is also an evidence of their greater importance; since, by the law of development, the portion of an organized being which is first produced, is regarded as the most essential, and as the *efficient cause* of those which succeed it. There are certain animals which appear to consist almost exclusively of fluids, as the jelly-fish, one of which, weighing fifty pounds, may be dried down to a weight of only as many grains. There are parallel instances among plants, in the case of certain fungi.

Although no vital action can go on without the presence of a

certain amount of moisture, still there are instances among the lowest tribes, both of animals and vegetables, where the entire loss of the fluids merely produces a state of *dormant* vitality, in which condition they may remain unchanged for any length of time. Among vegetables, we have examples of this in certain mosses and hepaticæ, which may be completely dried up, and yet be made to resume their verdure on being moistened. In like manner, the *wheel-animalcule* may be dried upon a piece of glass, and so preserved any length of time; but, on being moistened, it will become as active as ever. It appears, also, that many of the cold-blooded animals are reduced, by a moderate deficiency of fluid, to a torpid condition, similar to that produced by cold. Many of the mollusca, and even some fishes, exhibit this property, becoming torpid during the heat and drought of summer, but resuming their activity on the approach of wet weather.

As the various animals and plants are differently constituted in regard to the amount of fluid contained in their tissues, so are they found dependent, in very different degrees, upon *external* moisture. There is a beautiful adaptation of plants, particularly, to different situations, with this view; thus we find the Cacti and Euphorbiæ of the tropics growing in the driest and most exposed situations, often upon the bare rocks. These plants absorb a great deal of moisture, but exhale very little. On the other hand, those which grow in damp, sheltered situations, exhale moisture almost as fast as they imbibe it. Animals appear to be less influenced by external moisture than vegetables; in consequence, no doubt, of the mode by which they are supplied with moisture being so very different from that on which plants are dependent. Still, the hygrometric state of the atmosphere must produce some modifications, though they be not very obvious. It acts chiefly, by either increasing or diminishing the exhalation of fluid from the skin and pulmonary membrane.

While the above four essential conditions of life—*the germ-force, a plasmatic material, oxygen,* and *caloric*—are present, a healthy living organism must be the result; disease must ensue if any one of them be absent.

Plants and animals procure the means of their subsistence in a manner different from each other; the former, being fixed to the soil, cannot go in quest of the materials, but have them brought within their immediate grasp; animals, on the contrary, as soon as they commence their period of extra-uterine life (before which, they resemble plants), are forced to adopt means for procuring their supply from abroad; and for this purpose they have superadded to their organic functions a *nervous system*, which presides over the animal functions, or functions of relation, by means of which they obtain the power of locomotion. We may hence speak of Man as presenting two great circles, or spheres of life, totally distinct from, and independent of each other: the first, the *circle of organic life*, comprising the organic functions of digestion, absorption, respiration, secretion, and circulation; the second, the *circle of animal life*, including the functions of the brain (the psychological, and those of special sensation), and those of the medulla oblongata, and spinal marrow (excito-motor).

The circle of organic life has for its sole object the maintenance of the "indispensable conditions of life;" thus, it is the single object of *absorption* to replenish the blood with a healthy plasma; *digestion* prepares this material for use; *circulation* distributes it throughout the organism; *respiration* introduces oxygen, and removes an effete matter—carbonic acid; *secretion* either elaborates from the blood certain products, to be usefully employed in the economy, or else separates and carries off from it noxious principles.—The circle of animal life places man in relationship with his fellow-man, and with the exterior world. It enables him, by the power of his intellect and the energy of his will, to subdue all surrounding nature, forcing it to become tributary to his wants, and minister to his desires.

The organs of organic life are all enclosed within the trunk of the body, or are found upon the face; those of animal life are placed upon the exterior of the trunk,—as the brain, spinal marrow, spinal nerves, and muscles. The ganglionic or sympathetic nerve is a connecting link between both circles; it is placed within the

trunk. The brain is the organ through which the mind communicates with the external world. The spinal marrow presides over the reflex and automatic acts of the body; the function of its anterior columns is motor—through the nerves which proceed from its sixty-two distinct centres to the various external muscles of the body; the posterior column is excitor,—that is, it receives impressions made upon the nerves which take origin from its sixty-two distinct centres. By the combination of the two, excito-motor, or *reflex action* is produced, entirely independent of the will.

As before remarked, the spinal force has frequently been confounded with the vital force; but it is clearly only incidental to it. Moreover, it does not exist in vegetables, and the lowest order of animals breathe without it. The spinal or dynamic force is the efficient cause of locomotion; a very large amount of it is expended each day, in the ordinary movements of the body, though it is estimated that there is a saving of three-fourths in locomotion, arising from the compound nature of the levers of the foot and leg. The expenditure is rapid in proportion to the velocity employed; hence the fatigue from violent exertion. There is also a very considerable expenditure of the dynamic force in the functions of respiration, circulation, and digestion, as will be more fully explained hereafter. (Part IV.)

The well-marked distinction just pointed out, as subsisting between the two great circles of life, is exhibited also in pathology. Diseases may, in fact, all be classed under the one or other circle; thus fevers, inflammations, the different cachexiæ, &c., may be placed in the organic circle; in these, some one of the essential conditions of life must have been interfered with. On the other hand, all the neuroses, as palsy, apoplexy, epilepsy, neuralgia, &c., must be arranged under the circle of animal life; in these the *forces* also have been deranged. The difference between the two is farther evidenced by the fact that an individual may retain the one set of functions in the most perfect state of health, while the other is in a condition of incurable disease; thus, a patient with complete paraplegia may have his digestion perfect, and his nutrition unimpaired, and so continue for years.

PART II.

OF THE MATERIALS COMPOSING LIVING ORGANIZED STRUCTURE.

CHAPTER I.

OF THE ELEMENTARY PARTS OF LIVING STRUCTURES.

In attempting to investigate a complex mechanism like that of Man, experience demonstrates the propriety of first studying its component parts; when a thorough knowledge of these has been gained, and all their different operations understood, it will be comparatively easy to associate them together, and to study their combination of action, which constitutes the perfect machine.

SECTION I.

ORGANIC AND INORGANIC BODIES—ULTIMATE COMPOSITION, VARIETIES, ETC.

All bodies in nature may be divided into two great classes—the inorganic and the organic. The former are governed by the laws of physics; the latter by the same laws, together with those of vitality and intelligence.

The same chemical elements enter into the composition of both the above classes, with, however, this difference,—that out of the sixty-two elementary bodies at present recognised by chemists as found in the inorganic kingdom, only *eighteen* have ever been dis-

covered in organic matter; hence the latter is distinguished from the former by the small number of its chemical elements.

Again, these eighteen organic elements may be separated into two divisions, namely, the *essential*, comprising carbon, oxygen, hydrogen, and nitrogen, and so named because always found in organic matter, and the *non-essential* or *accidental* elements, consisting of sulphur, phosphorus, sodium, potassium, calcium, magnesium, manganese, iron, copper, silicon, chlorine, iodine, bromine, and fluorine. These are employed in the economy for certain specific purposes: thus lime, in combination with phosphoric and carbonic acids, gives solidity to bones; sulphur and phosphorus form a constituent part of albumen and fibrine; phosphorus exists in the nerve-substance, iron in the hæmatin of the blood, &c.

The four essential elements of organic matter constitute a distinct group, and from their very great importance they have received the name of *radical matter*. Their power of combining among each other appears almost unlimited, since it is by the simple difference in the grouping together of these four elements, with an occasional addition of one or two of the non-essential elements, that the vast diversity in organized matter is produced. Thus, several distinct series of compounds of carbon and hydrogen are formed by the addition of an atom of either constituent; and by decomposing urea, its four elements may be made to assume thirty or forty new organic forms; and so of many others.

Another point of difference between inorganic and organic bodies is the *mode of combination* of their elements. Inorganic bodies are chiefly *binary*, that is, are formed by the union of two different constituent atoms; and these atoms may be either *simple*, as in the union of oxygen and hydrogen to form water, or of oxygen and sodium to form soda;—or they may be *compound*, as in the case of sulphuric acid (sulphur and oxygen) with soda (sodium and oxygen), to form sulphate of soda. Organic bodies are rarely binary; usually they are ternary, or quaternary, or even higher; thus cellulose, starch, sugar, and gum (vegetable matter) consist of carbon, oxygen, and hydrogen; while *animal* matter contains

nitrogen in addition to these, and also very often sulphur and phosphorus, as seen in proteine.

As regards the *mode* of combination of compound bodies, there is some difference of opinion. Sulphate of soda, for example, may either be considered a compound of an acid oxide (sulphur and oxygen), with a basic oxide (sodium and oxygen), or one of these constituents may be supposed to be decomposed, yielding one of its elements up to the other, which thereby forms a *compound radicle*, to which the other element is suited;—thus the soda gives up its oxygen to the sulphuric acid, forming with it a compound represented by SO_4, which is supposed to unite with the sodium. According to this latter view, the oxy-salts would be *binary*, instead of *ternary* compounds, just as are the chlorides, iodides, &c. This view is adopted by Graham, Daniell, and others; and is of great interest when applied to the composition of organic bodies.

In compound bodies, the mere addition or subtraction of a single atom will often completely change their character. An example of this is given in the different compounds of nitrogen and oxygen; also in the two chlorides of mercury. But it is even more apparent in organic bodies; and this will serve to explain the numerous changes which are constantly going on in living beings. The principle of *isomerism* may also serve to explain some of these intricate changes. Bodies are said to be *isomeric* when they consist of the same elements united in the same proportions, but differing very much in their properics; starch, lignin, and diastase are examples; also light-carburetted hydrogen gas and the attar of roses. Isomerism is thought to depend upon the *different arrangement* of the constituent elements of a body; but it is more probable that different compound radicles are formed, which unite with a different number of simple elements, as before mentioned.

The *tissues* of vegetables all resemble each other closely in composition. When treated so as to separate them from the different matters which they contain, the substance remaining is termed *cellulose*. It is composed of carbon, oxygen, and hydrogen,—the two latter being in the proportion to form water; so that vegetable tissues may be regarded as *binary* compounds of carbon and

water. Some of the vegetable *products* (or those proximate principles found laid up in plants) are *quaternary*,—containing carbon, oxygen, hydrogen, and nitrogen, as vegetable albumen, vegetable fibrine, and vegetable caseine, which are very nearly identical with the corresponding principles of animals. The same is true also of the vegetable alkalies, as quinia, morphia, &c. There are other vegetable products which are *ternary*—as the oils, sugar, starch, &c.

Animal tissues are *quaternary*, and are chiefly composed of two proximate elements—proteine and gelatine. The former of these, though of a complex nature, acts as a simple body, forming definite compounds with the different simple elements, as oxygen, sulphur, &c. The mode in which gelatine acts, is not so well known.

The *animal products* are generally *quaternary;* some of them, however, are *ternary*, as fat, sugar of milk, &c., but there is some doubt whether these are not really *produced* by vegetables, and passed unaltered into the animal. Berzelius regards animal products as *binary:* he supposes them to be compounds of oxygen and an organic radicle, consisting of carbon, hydrogen, and nitrogen.

The *combining number*, or *equivalent* of a compound body, is high in proportion to the number of atoms which it contains; thus the equivalent of proteine is 5529, oxygen being 100.

From the above distinction results also a great difference in the *stability* of organic and inorganic bodies. Inorganic matter consists of elements which are so proportioned to each other as to be completely saturated; they consequently have no tendency to separate: thus the chemical elements of water are held together by so powerful an affinity as to require considerable force to separate them; the same is true of sulphuric acid, of oxide of lead, &c. Organic matter, on the other hand, has its chemical elements more loosely held together; they are seldom completely saturated, whence it follows that their decomposition is much more easily effected; the slightest disturbing causes sufficing to produce it. This is especially true of animal matter, which, when exposed to moisture and a slight elevation of temperature, is speedily resolved into its ultimate elements, carbon, oxygen, hydrogen, and nitrogen; and these assume the new combinations of water, carbonic

acid, ammonia, cyanogen, and, if sulphur be present, sulphuretted hydrogen. Vegetable matter is less prone to decomposition, since it contains fewer elements; thus, a piece of wood, if kept perfectly dry, will last for many years.

It can now be easily understood how the molecules of organic bodies, not being in a state of equilibrium with respect to each other, are susceptible of disturbance in various ways. And as these changes are constantly occurring in the living body, they deserve special attention.

1. By a new arrangement of the molecules, without the addition or subtraction of any matter, constituting *isomerism*. Isomeric bodies are those which have the same chemical composition, but whose properties are different. Starch, sugar, and dextrine are examples, all having precisely similar compositions; their difference being supposed to result from the mode of arrangement of their elements.

2. By what is termed the *action of presence*, or *catalysis*. By this term is understood a change produced in the molecules of a body by the mere presence of another body not undergoing change itself. We have a familiar example in the action of spongy platinum on a mixture of hydrogen and oxygen causing immediate combination and explosion. In this case it may probably be due to the condensation of the gases within the minute pores of the metal, by which they are brought down to their molecular state, and thus presented together under conditions most favourable for combination. In the same way, nitric acid is sometimes formed in the pores of old walls, by the condensation of the nitrogen and oxygen of the air; this combines, subsequently, with ammonia, and the nitrate of ammonia, thus spontaneously formed, is decomposed by potassa, so as to form saltpetre. We have numerous examples of this sort of action, both in vegetables and animals; thus the spontaneous change, in germinating seeds, of starch into dextrine and grape-sugar, through the catalytic action of diastase; a similar change is effected in starch by boiling it with dilute sulphuric acid—no change occurring, in either instance, to the catalytic body. A similar influence, it has been suggested, is exercised by the

living cells of the body, which are thus enabled to produce those changes upon their contents resulting in the varied products of secretion and nutrition. It is the *nucleus*, however, rather than the cell itself, that exercises this power.

3. The transference of action from the molecules of a body undergoing change, to the molecules of another body at rest, producing in it a similar change; this is termed *fermentation.* The presence of oxygen is always necessary to commence this process. A familiar illustration of it is exhibited in ordinary vinous fermentation, when the changes occurring in the yeast-cells are transferred to the molecules of the sugar, the proper temperature being preserved. It is highly probable that many of the changes produced in the animal fluids especially, are the result of this kind of action. For example, the digestion of albuminous food in the stomach is greatly facilitated by the *pepsin* of the gastric juice, which is thought to act as a ferment, converting the proteine elements into what Mialhe terms *albuminose*,—a soluble matter capable of being immediately absorbed into the blood. In the same manner contagious and malarial poisons probably produce their effects upon the system, by first contaminating the blood; the minutest quantity of variolous matter, for example, introduced into the blood, will, after a certain time, completely alter its character, so as from it to reproduce itself a thousand fold. The same thing is seen in the effects of the vaccine virus, and of the different poisonous animal viruses.

4. A process somewhat resembling fermentation, yet distinct from it, named by Liebig *eremacausis*, or *slow decay.* The only requisites for it are oxygen and moisture, the former being slowly absorbed. An example is afforded in the souring of wine and beer, when exposed to the air. This was formerly termed the *acetous fermentation;* but it wants the true character of fermentation, in not requiring a ferment. Eremacausis is a process of constant occurrence in the animal economy. It is by this means, through the agency of the oxygen introduced by respiration, that the tissues are unceasingly undergoing decomposition, giving rise to numerous secondary products found in the various secretions—

thus urea, uric acid, carbonic acid, ammonia, phosphoric acid, &c., are formed. If this process of disintegration or decay should, at any time, exceed the reparative process,—or that by which the system is constantly built up and renewed, through the nutritive elements of food,—the result must be emaciation, and ultimately death. Instances of this are exhibited in various chronic diseases, as phthisis, &c.

5. The chemical affinity among the molecules is greatest in their *nascent state*, that is, while they are in the act of change or separation. Thus, arsenic and hydrogen cannot be made to combine directly by any known agency; yet they readily unite if presented to each other while in the act of escaping from some of their compounds,—as when an arsenical preparation is added to the materials for generating hydrogen, instantaneous combination ensues, and the very poisonous gas, arseniuretted hydrogen, results. There is every reason to believe that this condition is constantly occurring in the living organism, since we know that the various compounds existing in the blood are unceasingly undergoing change, as already mentioned, and of course eliminating their elements in their nascent state, which immediately enter into new combinations.

Varieties of Organic Matter.—Organic matter consists of two varieties, *vegetable* and *animal*. In most cases there can be no possible difficulty in distinguishing between these, as their marks are sufficiently characteristic. When, however, we examine the extremes of these two varieties, the strong lines of distinction gradually fade away by the investigations of the organic chemist; since *cellulose*, a true vegetable substance, has been discovered to exist in the structure of some of the lowest animals. The true vegetable *products*,—starch, dextrine, and gum,—have never been found in animal structure.

Dextrine is the special organizable principle of vegetables. It is produced, as will be presently explained, by the action of diastase upon the starch of seeds. Dextrine constitutes the true vegetable plasma, since out of it are elaborated all the different fluids and solids of plants. As just mentioned, it does not occur in animals.

Proteine is the basis of animal organic matter, but it is likewise found in vegetables, though always as a product arising from the combination of the elements of dextrine with those of ammonia.

The most important proteine animal compounds are albumen, fibrine, and caseine; these will hereafter be treated of at length. The proteine compounds of vegetables are named vegetable albumen, vegetable fibrine, or gluten, and vegetable caseine, or legumin. *Neurine* and *gelatine*, varieties of animal matter formed out of proteine, are never found in vegetables.

Origin of Organic Matter.—Buffon supposed that it was originally produced from its elements independently of inorganic matter; but this idea is disproved by geological researches, which exhibit the universal fact of the primitive strata never containing organic remains. The question has often been agitated whether organic matter might not be spontaneously produced by some accidental meeting together of the chemical elements, carbon, hydrogen, oxygen, and nitrogen, without the necessity for a special apparatus for its creation. This idea has been maintained from the circumstance that urea and alloxan, two animal matters, can be artificially produced by the chemist; and, it was urged, the same might be possibly true of all organic matter. But it is to be observed that neither urea nor alloxan are true organic proximate elements; they are only the *products* of the decomposition of organic matter, and merely its intermediate state, before it passes into its original ultimate elements.

How then does organic matter originate? The living vegetable cell is the *exclusive* instrument of its production; the materials from which it is manufactured are water, carbonic acid, and ammonia; the agent is the sun's light. The chemist may indeed convert one organic substance into another, as starch into sugar, but he cannot out of simple inorganic matter, by the mere force of chemical affinity, no matter how powerful, *create* a single atom of organic matter. This wonderful transformation, is however, constantly going on in the living laboratory of the vegetable cell, which possesses the power of so acting upon the inorganic ele-

ments of the air and soil as out of them to constitute the numerous vegetable products and tissues. This is accomplished in the following simple manner: The vegetable cell is composed of a double wall,—an outer one, consisting of cellulose, and an inner one, called by Von Mohl the 'primordial utricle,' an exceedingly delicate membrane, consisting of a proteine substance; these cells exist throughout the whole structure of the plant, as well in the roots as in the leaves. The arrangement in the roots consists of an extremely fine mesh of cells, termed *spongioles*, which imbibe from the soil, by endosmose, water holding in solution ammonia, some carbonic acid, and various salts of soda, potassa, lime, and silica, together with certain organic acids, of which the *ulmic* is the most important; these acids combining with the ammonia, tend to fix it. Most of the carbonic acid is absorbed from the air by the cells of the leaves and green portions of the plant; and in air-plants, which have no proper roots, the ammonia must be derived in the same manner. The next step is the decomposition of the carbonic acid and ammonia: the force concerned in the former is *light*, more especially the yellow ray of the solar spectrum, as proved by Prof. Draper; this force acting, deoxidizes the carbonic acid, the oxygen of which escapes into the air, whilst the carbon, in its nascent state, unites with the elements of water (or, according to Raspail, with water itself), and thus *dextrine*, the peculiar vegetable product is constituted.

Having formed dextrine, the whole amylaceous series, comprising starch, cellulose, gum, and sugar, may be considered as likewise produced, since these bodies are all isomeric. From these the vegetable acids are formed by the simple addition of oxygen; whilst the vegetable oils and resins are produced from the same source, by the abstraction of oxygen.

The above is the first step in vegetative life-action. It consists, as will be observed, in the production of true vegetable matter, which contains no nitrogen. The next step in the process is the conversion of this into *nitrogenised*, or animal matter; and the mode of effecting this is equally simple. The dextrine within the vegetable cell forms with water a gummy solution, and thus offers

the proper conditions for an endosmosis from the water on its outside. This water, it will be recollected, is derived from the soil, and holds in solution a considerable quantity of ammonia. There exists in the roots a minute portion of a proteine matter, similar to the diastase of the seed, and seeming to act a *catalytic* part,—disposing the elements of dextrine to unite with the nitrogen of the ammonia. The ammonia, then, after passing into the interior of the cell, undergoes decomposition; its nitrogen in the nascent state uniting with the dextrine to convert it into vegetable proteine matter (vegetable albumen, gluten, &c.); the sulphur and phosphorus necessary to its constitution, being derived from the earthy sulphates and phosphates taken up from the soil at the same time.

By passing from cell to cell in its upward progress, the ascending sap undergoes higher elaboration, forming successive new products, as the acids, gums, resins, &c., which are deposited in different parts of the plant. The various forces which are here in action are heat,—the importance of which has already been shown, light, endosmose, and the molecular forces.

From the above consideration it is evident that vegetables are the true manufacturers of proteine, or animal matter. Animals really originate nothing. The animal cell, however, possesses the exclusive power of modifying this matter when presented to it, and causing it to assume new forms; thus, it converts common proteine into gelatine and neurine; and forms the different tissues and organs.

Vegetable matter, thus produced, becomes the appropriate food of animals. In its transit through the animal economy, it undergoes various changes through the decomposing agency of oxygen; a portion of it being destined for the nutrition of the tissues, and a portion for furnishing the elements of combustion for the maintenance of animal temperature. Both, however, become decomposed,—first, into the various products set free by the secretions, as carbonic acid by the lungs, ammonia (in the form of urea) by the kidneys, water, by the skin and lungs, together with the different salts. These substances again return to their former condition in the atmosphere and soil, once more to serve

as the inorganic material for the constitution of other new vegetable matter. In this manner a constant circle of creation is preserved; inorganic matter entering into the formation of vegetables; these, in their turn, constituting animal matter; and this, finally, passing back again to the original state of inorganic matter.

Two inferences result from this consideration. First, that the creation of the vegetable world must have preceded that of animals; since the latter can derive their sustenance only from the former;* secondly, that the inorganic creation was antecedent to the organic; because vegetables can only grow by the appropriation of inorganic materials. The above physiological discoveries are strongly confirmatory of the doctrine of an original creation of matter, and likewise of a supreme and intelligent Creator.

As the inorganic series serves to form organic matters, as has been just demonstrated, so, on the other hand, organic materials often contribute to the building up of inorganic matter. Thus, it has been ascertained that many rocky strata are chiefly composed of fossil organic remains; this is especially true of the chalk cliff of Dover. This fact has given rise to the Linnæan aphorism "omne calx e vermibus." Ehrenberg proved the same thing with respect to the silicious rocks, whence the aphorism, "omne silex e vermibus." The same thing also is to a great extent true, of some forms of iron; the bog iron-ore being found to be gradually reproduced from animal remains, in situations from which it had been removed.

Conditions of Organic Matter in Living Beings.—In living beings, both vegetable and animal organic matter will be found to exist under the following several different conditions, which may be considered as so many species:—1. *Organizable matter*, or that which is susceptible of becoming organized, or of taking on an organized form. As we have already seen, the true organizable matter of animals consists of a proteine substance—albumen; that of vegetables is dextrine. The former is capable of being con-

* The *infusoria* may possibly form an exception to the above law, since they, like vegetables, eliminate oxygen, in their vital processes.

verted by life-action, into fibrine, caseine, gelatine, &c.; the latter, into the different vegetable products. 2. *Organized matter*, or matter which has passed out of the preceding state, and assumed a definite specific form. The vegetable kingdom affords us examples of organized matter in cellulose, lignin, and cells; animals furnish instances of it in corpuscles, cells, fibres, membranes, muscles, and nerves. The cause of the *speciality of form* which is given to each variety of organized matter, is explicable only on the supposition that each living germ is endowed with a peculiar power of modelling the organizable material after its own type. This property of the germ has received the appropriate name of the *modal force*, or the *force of modality*. 3. *Inorganizable matter*, or matter incapable of becoming organized. This is usually found as the products of the different secretions or excretions. It consists of two varieties: (*a*) *normal* —as urea, bile, milk, saliva, mucus, the spermatic fluid, &c.,— found in animals; and starch, sugar, gum, oils and resins, in vegetables. (*b*) *Abnormal*—as pus, sanies, contagious matters, viruses, melanosis and tubercle, in animals;—in vegetables, ergot and galls. Many of the inorganizable products of animals are nothing more than the results of the disintegrated tissues, in their transition state to their ultimate chemical constituents;—urea is a well-marked example of this transition.

The animal organizable material, or the *plasma*, contains within itself all the elements of the tissues and organs of the body. In its original state it is always fluid. In most animals it is elaborated from exterior materials by the digestive process. The mode of its supply will of course vary according to the nature and habit of the animal, but it is of the greatest importance that this supply, as regards both quantity and quality, should be adequate to the incessant requirement of the organism. This material is needed, not only for the growth of the animal, but likewise for the renewal of what is lost by the ordinary waste or disintegration of the tissues, in the performance of their usual functions. This loss is estimated to be about two ounces per diem, from the nitrogenized tissues. An abundant supply of this plasma is insured to every

living molecule of the body, through the numerous and intricate capillary retes; and the smallness of the vessels, together with the closeness of the rete, is always in proportion to the activity of function in any organ; thus, in bone and cartilage, where the function is inactive, the capillaries are large, but few in number; whilst in glands and mucous membranes, whose functions are performed with great rapidity, the rete is very close and intricate, but composed of very minute vessels. From the fact that each organ has its own specific capillary arrangement, Burdach has called the capillary system "the stereotyped expression of the organs;" and a minute corroded injection of any one of them would afford a certain evidence of the relative activity of its functions.

It follows, from what has just been said, that when the function of any part of the system becomes exalted above its normal standard, a greater amount of blood must flow into it from surrounding parts, in order to afford it the requisite supply: this is illustrated in cases of local irritation, when the parts affected always become more vascular than in health. Such a condition, constantly kept up, is very liable to terminate in inflammation, as is frequently witnessed in the brain of persons whose minds are in constant and intense excitement.

It is of the greatest importance to pay due attention to the plasma, since it is the pabulum of the whole body. Now, as this is constituted from the nitrogenized portion of the food, it becomes of the utmost consequence that the latter should be of the proper character. But we need not pursue the subject farther, in this place, since it has already been sufficiently enlarged upon. (Part I.)

States of Organic Matter.—Organic matter exists in two different states—the solid and fluid. The concurrence of the two is indispensable to life, though the fluid must always precede the solid in the organizing process. Some consider the fluid to be the element of life, and the solid the product of life. They are most intimately associated in disease as well as in health; nor can they be separated in therapeutics. The doctrines of the *solidists*

or *humoralists* prevailed according as the solids or fluids of the body were believed to be chiefly implicated in disease.

The proportion between the solids and fluids varies exceedingly in different animals. A medusa, weighing twelve pounds, will, when dried, only yield a few drachms of solid matter. The proportion also varies in the different tissues of the same animal; thus, in bone, cartilage, ligaments, &c., the solids predominate; in glands, mucous membranes, &c., the fluids are in excess. Even in the same organ, the proportion is not at all times the same, since the fluids always increase in congestion and inflammation. As already mentioned, the supply of blood to every organ is regulated by the activity of its functions; and any deviation from this will constitute disease. Thus, when the blood is in excess, hyperæmia is the result, followed by hypertrophy and plethora; when deficient, anæmia is produced, and atrophy is a frequent consequence.

The fluids are much more under the control of remedies than the solids; thus, bloodletting acts powerfully, both in diminishing the quantity of the circulating material, and by changing the direction of its current, especially when locally abstracted by cups and leeches. By diet, also, the plasma (fluids) may be materially modified, if not completely revolutionized, as is witnessed in the dietetic treatment of certain chronic diseases.

CHAPTER II.

PROXIMATE CONSTITUENTS OF THE ORGANISM.

THE *proximate organic elements* are those forms of organized matter which are the immediate result of the chemical combination of the ultimate elements in the process of organization. They are sometimes spoken of as the principles which exist ready formed

in organic beings. Starch, gum, and sugar are examples of proximate constituents in vegetables; albumen, fibrine, and gelatine are instances of the same principles in animals.

The organic proximate elements may be conveniently arranged under the four following groups, or classes:—1. The proteine group; 2. The gelatine group; 3. Neurine, or nerve-substance; 4. Hæmatine. These principles may be regarded as the true building materials of the animal structure, since out of them are constituted all the different organs and tissues of the economy. As it is of the utmost importance that they should be properly understood by the student, in order that he may appreciate their various modifications and functions, both in the healthy and diseased structure, they will be treated of separately, and somewhat at length.

SECTION I.

THE PROTEINE GROUP.

This class comprises the following seven proximate constituents: albumen, fibrine, caseine, pepsin or animal diastase, salivin or ptyalin, globuline, and crystalline.

The name *proteine* was given by Mulder to a substance obtained from albumen: it is derived from the Greek πρωτευω, *I take the precedence*, and has reference to the important relations which it bears to the animal organism. It is procured from either albumen, fibrine, or caseine, by dissolving in a moderately strong solution of caustic potassa, digesting at 140° F., adding subacetate of lead until it ceases to blacken; then filter, and add acetic acid in excess, which throws down a white, flocculent precipitate: this is proteine; it is next to be placed upon a filter, washed, and dried. It is a whitish, flocculent substance, without taste, resembling caseine, insoluble in water, but swells up in that liquid. A dilute alkali will readily dissolve it, but acids precipitate it from its solution. Its composition, as originally determined by Mulder,

is $C_{40}H_{31}N_5O_{12}$; according to Liebig, $C_{36}H_{25}N_4O_{10}$ + one equivalent of sulphur.

In repeating Mulder's experiments for obtaining proteine, Liebig found that it always contained sulphur and phosphorus, and he was hence disposed to deny its existence altogether. Subsequently, Mulder himself has admitted the correctness of Liebig's views, and has so modified his formula for proteine, as to make it embrace both phosphorus and sulphur.

There are two methods of interpreting the production of this remarkable substance. It may be that it pre-exists in the natural albuminous principles, which, on that supposition, must be viewed as compounds of proteine, with sulphur and phosphorus, or with sulphur only: or it may be regarded as merely a *product* of the action of the alkalies on these bodies, the sulphur and phosphorus being at the same time separated.

Proteine exists both in vegetables and animals; in the former as a product, in the latter as a part of the structure. Animals always derive it ready formed from vegetables. The seeds of plants, and the tissues of animals present it in the solid form; the leaves and roots of plants, and the animal fluids exhibit it in the liquid form. In plants or animals, it is readily converted from a liquid into a solid, by meeting with an acid. In this manner we can account for its deposit in the cells of plants, and also for the formation of certain morbid products in the animal economy. An alkali, on the other hand, will dissolve solid proteine; and, in this way, the efficacy of the alkaline treatment, in certain forms of disease, can be explained.

Proteine enters into numerous combinations: with oxygen it unites in several proportions, forming the *binoxide of proteine*, $C_{40}H_{31}N_5O_{14}$, and *tritoxide of proteine*, $C_{40}H_{31}N_5O_{15}$. The former of these is insoluble; the latter is soluble. They are both supposed to exist in definite quantities in healthy blood, being formed in the process of respiration. In inflammation they accumulate, and constitute the chief ingredients of the *buffy coat*, being produced at the expense of the fibrine. The principle found in pus, named *pyine*, is

believed to be a protoxide of proteine. A still higher oxidation constitutes *pepsin* and *ptyalin*; and Mulder asserts the existence of an oxy-proteine, in which the oxygen is in the proportion of twenty parts.

With sulphur and phosphorus proteine forms a number of very important compounds; in fact, these are the only combinations in which proteine naturally exists in either vegetables or animals. The following is a list of some of these proteine-compounds:—

Albumen of serum, - - - -	$Pr+S_2+P$.
Albumen of eggs, - - - - -	$Pr+S+P$.
Fibrine, - - - - -	$Pr+S+P$.
Caseine, - - - - - -	$Pr+S$.
Crystalline, - - - - -	$Pr+S$.

Similar compounds to the above are found in vegetables, and are named respectively, *vegetable albumen*, *vegetable fibrine*, or *gluten*, and *vegetable caseine*, or *legumin*. These all contain nitrogen, and are regarded by Mulder as identical in composition with the animal proteine elements; Liebig, however, does not admit their complete identity. The precise *mode* of combination between proteine and sulphur and phosphorus is not well understood; but it is believed that the two latter exist as *amides*, constituting *sulph-amide* and *phosph-amide*. Besides the above proteine-compounds there are numerous others, of a similar character, whose exact composition is not yet known, such as hair, horns, nails, &c.

Proteine also unites with acids and alkalies: with the former as a base, with the latter as an acid, forming a soluble *proteate*. With sulphuric acid it forms *sulpho-proteic acid*; with nitric acid, *xantho-proteic acid*.

1. *Albumen.*—$C_{40}H_{31}N_5O_{12}+P+S_2$.—This principle is found in the white and yellow of eggs, in the serum of blood, in the humours of the eye, in serous exudations, in the urine under certain diseased conditions, and in various morbid products, as tubercle, &c. As found in the egg, and in the serum of the blood, it differs

slightly in composition; the former (*ov-albumen*) containing one equivalent less of sulphur than the latter (*ser-albumen*). In vegetables it exists in the seeds and juices; some plants, as the cabbage, consist almost exclusively of this principle combined with gluten, with little or no starchy matter; for this reason it is well adapted as an article of diet in diabetes mellitus, a disorder in which there is a tendency to convert all non-azotized food into sugar.

Albumen exists in two states, the fluid and solid. When perfectly pure, it is always solid; and its natural solubility in the serum of the blood, and in other albuminous fluids, is owing to the presence of a little free soda, and the salts of soda and lime. When precipitated in its pure state, it is nearly colourless, inodorous, and tasteless. Its characteristic property is its coagulation by heat. The temperature required for this purpose varies with the state of dilution. If the solution be so strong as to have a slimy aspect, a heat of 150° to 160° F. will suffice; but if very dilute, a boiling temperature will be required. Coagulated albumen presents no traces of organization. It is solid, white, and opaque; it dries up into a yellow horny substance, which, when macerated in water, assumes its former whiteness and opacity. When coagulated at a very low temperature, it will re-dissolve in water. The only chemical change which occurs during the act of coagulation by heat is the removal of the alkali and the soluble salts by the hot water. Coagulated albumen exposed to a moderate temperature and moisture, soon undergoes putrefaction, developing animalcules; but if slightly acidulated, this does not occur; a copious, mould-like vegetation taking its place. Albumen is likewise coagulated by tannin, alcohol, creasote, and electricity; when acted upon by electricity, the albumen appears at both poles,—at the positive pole, in union with hydrochloric acid, and at the negative, in union with soda. According to Chevreul, ether and oil of turpentine coagulate the albumen of eggs, but not that of serum.

Albumen unites with acids as a base, and with alkalies as an acid. Most of the acids in excess will precipitate it from its

solution, forming compounds with it; but the acetic, tribasic (common) phosphoric, lactic, and tartaric acids dissolve it in all proportions. The gastric juice of the stomach owes its acidity to the presence of some of these latter acids; and it is doubtless to them that its solvent power over the albuminous elements of food is due. United with the alkaline earths in small proportion, albumen is soluble; with a large proportion it is insoluble. It forms insoluble compounds with the salts of the metallic oxides, but the albumen is divided between the base and the acid; hence its value as an antidote in cases of poisoning from corrosive sublimate, or the salts of copper.

The chemical relations of albumen are interesting in a therapeutical view. Thus, in cases where the acetate of lead is employed as a collyrium in inflammation of the eye, if there is an open ulcer of the cornea, the lead would unite with the exposed albumen of the tissue, and form an insoluble compound, which would result in a permanent opacity of the cornea. The insoluble compounds of albumen and the metallic oxides become again soluble when they meet with the alkaline chlorides in the alimentary canal; hence, in cases where albumen has been given as the antidote, it should be accompanied by a cathartic to remove the resulting compound from the bowels as soon as possible. The different degree of solubility of certain poisonous substances, when united with albumen, will explain very satisfactorily the difference in their poisonous effects; for example, the cyanide of mercury produces an almost immediate effect, because it forms a *soluble* compound with the albumen of the stomach, and is consequently readily absorbed into the blood; whilst corrosive sublimate, under the same circumstances, forms an *insoluble* compound, which requires the subsequent action of the alkaline chlorides before it can be re-dissolved, and enter the circulation. For the same reason, nitric acid does not act as a poison so promptly as oxalic acid, though a far more powerful acid than the latter, because it forms an insoluble compound with the albumen.

The proportion of albumen in the serum of the blood is just that which is sufficient to enable it to dissolve the phosphate of lime,

and thus to furnish the material for the construction of bones. The best tests for albumen are its coagulability by heat and nitric acid; also one recommended by Prof. Rogers,—a dilute solution of sulphate of copper added to liquor potassæ; a purple colour is produced. There are likewise other tests of inferior value. Corrosive sublimate, as already mentioned, will immediately precipitate albumen: four grains of it will neutralize the white of one egg.

Albumen, as such, does not enter into the construction of any healthy tissue of the body; it is rather the point of departure at which the organizing process commences. It is the crude material furnished by the nitrogenized food, and destined to undergo the various transformations in the vital processes.

2. *Fibrine.*—$C_{40}\ H_{31}\ N_5\ O_{12}+S+P$.—Isomeric with albumen, and is generally regarded as produced from it by the process of organization. Dumas supposes it to be an oxidized albumen. M. Banard's opinion is that much of the albuminose, resulting from the digestive process, is transformed at once into fibrine, as it passes through the liver. His ground for this notion is that the portal blood contains most of the digested azotized matter, and but little fibrine, even when the animal had been fed upon meat; whereas the blood of the hepatic veins contains much fibrine, and but little albuminose; and further, that this difference is only observed during digestion. The only method of distinguishing liquid fibrine from albumen is by the spontaneous coagulation of the former, which is its characteristic test.

Fibrine is found in the animal body in two forms; as a *solid*, in muscular flesh, and as a *liquid*, in blood, lymph, and occasionally in dropsical effusions, and in urine in disease. It exists likewise in the gluten of the cereal plants, and in the juices of certain vegetables. It is best procured from blood, either by washing the coagulum until all the soluble parts are removed, or by agitating it as it flows from a vessel, with a bundle of twigs, to which it will adhere, then washing it in cold water, and removing the fat by ether. When thus procured, it is in the form of long, white, elastic filaments, which, under the microscope, appear to be com-

posed of small globules, arranged in strings; it is tasteless, and insoluble in water, either hot or cold. By long boiling it is partially dissolved. When dried at a gentle heat, it loses about 80 per cent. of water, and is converted into a translucent horny substance, resembling coagulated albumen. It dissolves completely in a dilute solution of a caustic alkali, and the solution much resembles that of albumen. Phosphoric acid produces a similar effect. Nitric acid converts it into xantho-proteic acid. It is soluble in a dilute alkali. It is readily converted into albumen by the process of digestion; and like albumen, it acts both as an acid and a base. It also unites with the earthy phosphates.

In the act of coagulating, fibrine assumes a peculiar fibrillary arrangement, very much after the manner of crystallization; as is witnessed particularly in the buffy coat of inflammation. But the most perfect specimens of fibrous structure, produced by simple coagulation of fibrine, are found in the exudations from inflamed or wounded surfaces, constituting *false membranes;* also in the fibrous coating which the ovum receives as it passes along the oviduct, which afterwards becomes the shell. The completeness of the production of such tissues depends, partly upon the degree of elaboration of the fibrine, and partly upon the nature of the surface on which the coagulation takes place. This is believed by many to be the first step in the organizing process; and it is very possible that some of the primitive fibres of the body may be in this manner formed, without the intervention of cells.

The tendency of fibrine to undergo spontaneous coagulation has already been noticed; to this cause alone is due the disposition of the blood to coagulate, as is proved by the experiment of filtering a frog's blood,—the liquid portion which passes through alone coagulates, the corpuscles remaining on the filter. The same thing is also shown in the process of procuring fibrine by whipping freshly-drawn blood with a bundle of twigs. The degree of firmness of the coagulum depends upon the amount of fibrine present. The normal proportion of fibrine in blood is from 2·5 to 3 parts in a thousand. The reason why the blood does not coagulate in the living body is probably because the contact with a living surface

keeps it within the influence of vitality, or, as suggested by Dumas (who believes the fibrine of the blood to be always in a state of minute division, and not of solution), because it is passing out of the circulation for the supply of the various organs, as rapidly as it is elaborated.

Fibrine was at one time supposed to be the *immediate plasma*, or material for the construction of the organism; but the discovery of the oxy-proteines renders it probable that it is only in the transition state. The accumulation of fibrine in inflammation is to be considered rather as an increase of the oxides of proteine, as already pointed out, when treating of proteine. Blood deficient in fibrine,—as seen in certain low forms of fever, retains its dark venous hue when exposed to the influence of oxygen.

The above is the commonly-received doctrine upon the origin and destination of fibrine in the animal economy. The recent views of Dr. Simon (*Gen. Pathol.*) are strongly opposed to it. From numerous observations made by himself and others, he found that the proportion of fibrine in the blood very decidedly increased in diseases essentially anæmic, during violent fatigue, and the like, in some cases even beyond what was found in inflammation. In one case of experimental starvation of a horse, he found, after four days' total abstinence, that the proportion of fibrine had risen from five to nine parts in the thousand. It is also well known that bleeding does not diminish the amount of fibrine, but, on the contrary, rather appears to augment it; this is confirmed by both Andral and Scherer. It is just the reverse with respect to the red corpuscles, which are uniformly diminished by bleeding and starvation, or exhausting diseases. From the above facts Simon questions the theory that fibrine is essential to the progressive development of the tissues, but regards it rather as an excrementitious product, derived from the waste of the tissues, or oxidation of the blood, and in progress of elimination from the system. On this view, any increase in the proportion of fibrine must be regarded only as an indication of increased labour and waste in certain elements of the body, not of an increased development in the resources and nutrition of the blood; and the super-fibrination of the blood

in inflammatory diseases would be considered rather as their consequence than as their cause.

The fibrine of arterial and venous blood is not absolutely identical; the latter when treated with one-third of its weight of nitrate of potassa and water, at the temperature of 100°–120° F., is converted into a solution in all respects identical with albumen. With arterial fibrine no such liquefaction ensues; and even venous fibrine loses this property when long exposed to the air or oxygen gas. The fibrine of muscular flesh resembles venous fibrine.

A peculiar point of distinction between albumen and fibrine is the effect of the latter upon deutoxide of hydrogen,—causing its instantaneous decomposition.

3. *Caseine.*—$C_{40}H_{31}N_5O_{12}+S$. This is the coagulable portion of milk, and the basis of cheese. Milk, as shown by Prout, contains all the different forms of aliment within itself; the albuminous are represented by caseine, the saccharine or amylaceous by lactine or sugar of milk, and the oily by butter. It also contains several alkaline and earthy matters.

Caseine exists in minute quantities in the blood, bile, urine, pus, and crystalline lens (Simon); never in any of the solids in health, but only as a morbid product, as in tubercle. It closely resembles albumen, and may easily be mistaken for it; like that substance it is insoluble when pure, and owes its solubility to the presence of a small quantity of alkali. It differs from albumen in not coagulating by heat, and in being precipitated by acetic acid, which dissolves pure albumen. Another distinction is that it contains no phosphorus. Unlike albumen and fibrine, caseine does not combine with acids, though with bases it plays the part of a feeble acid. It is easily convertible into albumen and fibrine, as seen in the digestive and nutritive processes of young animals.

The spontaneous coagulation of milk, when allowed to rest for a time, is due to a species of fermentation by which the sugar of milk is converted into lactic acid through the agency of the caseine; this acid then neutralizes the alkali of the milk, and consequently precipitates the caseine in its natural solid form. Two equivalents of lactic acid, 2 $(C_6H_6O_6)$ are yielded by every single equivalent of

sugar of milk ($C_{12}H_{12}O_{12}$). Any acid will in this manner produce coagulation in milk; but the effect of *rennet*, or the inner coat of a calf's stomach, in causing this change is remarkable,—a piece of rennet coagulating 1800 times its own weight of milk. This power of the mucous membrane is, by some, attributed to the acid of its gastric juice; but the same effect is produced even when the acid is neutralized by an alkali; it is doubtless owing to the *pepsine* contained in the membrane of the stomach, which has been shown by Berzelius to be capable of coagulating 45,000 times its weight of milk. Liebig supposes the pepsine to act merely as a ferment, converting the sugar into lactic acid; and Simon has proved that if milk be deprived of its sugar, the pepsine fails to produce coagulation. Fresh milk contains no lactic acid, but is, on the contrary, feebly alkaline. Human milk retains its alkaline character longer than any other kind.

Milk will be treated of more at large under the head of Secretion.

4. *Pepsine*, or *Gasterase.*—This organic principle was so named by Eberle, from πεπσις, *digestion.* It was first isolated by Wasmann, though its existence had been previously asserted by Schwann. It is contained in the epithelium cells of the mucous membrane of the stomach. During the process of digestion a rapid desquamation or moulting of these cells takes place; they then burst, and throw out the pepsine which mingles with the acids of the stomach, constituting the *gastric juice.* It is obtained by macerating the mucous membrane of a stomach for some time in water at a temperature of 90° F., then precipitating with subacetate of lead, removing the lead by hydrosulphuric acid; next evaporate and precipitate by means of absolute alcohol, and dry it. It is a white, powdery substance, soluble in water. Like albumen, it is coagulated by alcohol and the acids; an excess of the latter will redissolve the precipitate. It is also precipitated by the metallic salts, as corrosive sublimate, acetate of lead, sulphate of copper, &c.; but it may be separated from these again without losing its peculiar digestive properties. It differs from albumen in being precipitated by acetic acid.

The empirical formula for pepsine, given by Vogel, is $C_{48}\,H_{32}\,N_8\,O_{10}$. By comparing this with Liebig's formula for proteine, $C_{48}\,H_{32}\,N_6\,O_{12}$, it may be regarded as formed from proteine by the abstraction of two equivalents of oxygen, and the addition of two equivalents of nitrogen.

Pepsine is characterized by the function which it performs in the digestive process; this may be stated to be to facilitate the solution of the proteine materials of the food in the acid liquor of the stomach. So great is its solvent power over the proteine compounds that a slightly acidulated solution, containing only 1-60,000th part of pepsine will dissolve coagulated albumen in a few hours. There is no doubt that the real solvent in this case is the acid, as is shown by performing artificial digestion, out of the body, with an acid solution alone; this will dissolve albumen and fibrin after a certain time, provided the temperature be kept at 212° F.; but if a minute portion of pepsine be present (as when a piece of mucous membrane of a stomach is macerated in dilute hydrochloric acid), the solution occurs as before, but at the much lower temperature of 100° F. Hence, it would appear that it is the function of pepsine, in the process of digestion, to supply the place of an elevation of temperature which could not exist in the stomach. Liebig supposes it to act by fermentation. The pure alkalies destroy its power as a solvent.

5. *Ptyaline*, or *Salivin.*—This substance was discovered by Mialhe in the saliva, and was by him named *animal diastase*, from the analogy of its function with that of the diastase of vegetables. In the germinating seed, the starch undergoes a conversion, through the agency of diastase, into dextrine and glucose—soluble substances, which can be appropriated to the growth of the plant. In the same manner, it was maintained that the starchy constituents of food—comprising more than three-fourths of the whole—are acted upon by the animal diastase of the saliva, by which an insoluble material, incapable of being absorbed, is converted into a soluble matter — grape-sugar (glucose), which may then immediately enter the blood-vessels from the stomach; this glucose speedily undergoes a further decomposition in the blood into lactic acid

and the lactates, which, in their turn, are rapidly resolved into their ultimate elements, yielding up a large amount of carbon and hydrogen for union with the oxygen taken in by respiration, and thus maintaining animal heat.

Ptyaline may be obtained by the action of absolute alcohol on saliva, in which it exists in very minute proportions. It is a white, flocculent solid, soluble in water and in dilute alcohol. It does not differ in its properties from ordinary diastase; one part of either is capable of transforming 2000 parts of fecula into sugar. It is not furnished, as was first supposed, by the true salivary glands,—since the secretion of none of them, either separately or conjoined, according to Bernard, produces any effect on starchy matters, but from the small buccal and labial glands.

6. *Globuline.*—This principle occurs in the red corpuscles of the blood, associated with hæmatine, with which, however, it is not chemically combined, since they are easily separated by water. It is probably merely a modification of fibrine. Simon regards it as a peculiar form of caseine. Mulder's formula for it is $Pr_{15}+S$. The globuline constitutes the cell-wall of the blood-disc; in a colourless solution it may be made visible by the addition of iodine.

7. *Crystalline.*—This proteine constituent derives its name from being found only in the crystalline lens of the eye, associated with albumen; it forms 10 to 14 per cent. of the lens. It strongly resembles caseine in appearance and properties. It is not coagulated by heat, and is dissolved by boiling alcohol.

Pyine—the peculiar matter of pus, is regarded by Mulder as a protoxide of proteine.

SECTION II.

THE GELATINE GROUP.

Gelatine can scarcely be regarded as a true proximate constituent of animals, since it is procured from the tissues only by a continued

process of boiling. The gelatinous tissues constitute by far the largest portion of the animal system: they comprise the skin, mucous and serous membranes, areolar tissue, bones, cartilages, ligaments, and tendons. Gelatine has not been discovered in any of the animal fluids nor secretions; nor does it exist in vegetables. Familiar examples of it, in different degrees of purity, are afforded in isinglass, size, and glue; isinglass is the dried swimming-bladder of the sturgeon, which readily dissolves in warm water, and yields a very pure gelatine; common size is derived from serous and cellular membranes; glue, which is the most impure form of gelatine, is procured from the skins, cartilages, and hoofs of animals; it requires long boiling to dissolve it.

Müller has shown that there are two distinct forms of gelatine, to which the names of *chondrine* and *collin* (*glutin* or *gelatine*) have been given; they are distinguished, chemically, from each other by acetic acid, acetate of lead and alum, which precipitate chondrine, but not glutin. The formula for glutin or collin is $C_{13}H_{10}N_2O_5$; for chondrine, $C_{16}H_{13}N_4O_7$. The cause of the difference between the two varieties is unknown. Collin, or true gelatine, is obtained from skin, serous membranes, tendons, bones, fibro-cartilages, and cartilages when ossified. Chondrine is yielded by the permanent cartilages, bones of the fœtus, and bones in a fungous state; hence it would appear to be a degenerated condition of the other form of gelatine.

Gelatine is a hard, semi-transparent substance, soluble in boiling water, the solution having the property of solidifying on cooling; one part of gelatine in one hundred parts of water, exhibits this property. Its characteristic test is tannic acid, which yields with its solution a copious insoluble precipitate—the *tannate of gelatine;* this will detect one part of gelatine in five thousand parts of water. It is doubtless by their *chemical* influence upon the gelatine of the tissues, that the vegetable astringents produce much of their local effect.

The origin of gelatine in the animal system is not understood. The gelatinous tissues must be derived by some transformation of proteine, since they are developed in young animals fed exclusively

on albuminous matter, and also in herbivorous animals. Mulder supposes it to result from the action of the alkalies of the blood upon proteine, through the agency of oxygen. No method is known by which gelatine can be converted into proteine; hence it is probable that the use of gelatine, as an article of diet, is confined simply to the repair of the gelatinous tissues of the body; still it would appear that it must undergo decomposition, since all attempts to detect it in the blood have failed. Experiments made on a large scale, in France, with reference to the value of gelatine as an article of food, establish the fact that it is incapable of sustaining life, if used *exclusively*; the same thing is true, however, of perfectly pure fibrine; in neither case, will the animal live for any length of time, because deprived of the calorifacient elements of food, which are indispensable for maintaining the normal temperature of the body. It may be observed, that when employed as an article of diet for the sick, the jelly prepared from calves' feet, or from pure isinglass, is much preferable to that obtained from the common gelatine of the shops, which has been formed from cartilage.

By boiling gelatine with a caustic alkali, and the subsequent action of sulphuric acid, a sweet crystallizable principle is obtained, named *glycocoll*, or *gelatine-sugar*, containing $C_4H_4O_3N$. This substance has also lately been procured by the action of acids upon hippuric acid, which is thereby resolved into benzoic acid and glycocoll. It is possible that the existence of this principle may account for the existence of sugar in the urine of certain diabetic patients, even when their diet is exclusively animal. M. Bernard has lately ascertained the uniform existence of sugar in the liver, and in the blood of the right auricle, and hepatic veins. In certain rare cases, there exists a universal degeneration of the gelatinous tissues of the body, producing a wasted condition of the ligaments, &c.

The other two proximate bodies—NEURINE and HÆMATINE will be treated of subsequently.

The above four groups may be considered as embracing all the proximate azotized constituents of animal organic matter; they

furnish all the essential materials for the construction of the tissues and organs. There yet remains to be described a second class of animal principles, termed *secondary constituents of animals,* so named both from their subordinate importance, and from the fact of their being generally the results of secondary transformations out of the proximate constituents.

SECTION III.

SECONDARY CONSTITUENTS OF THE ORGANISM.

These may be conveniently considered under the two divisions of the *azotized,* and the *non-azotized* principles.

I. The Azotized Secondary Constituents of Living Beings.—These principles are all contained in the fluids, in which they exist as the results of the metamorphosis or disintegration of the proximate constituents, in the processes of life. In health, their amount in the different secreted fluids of the economy is always definite; so much is this the case, that an abnormal quantity of them, occurring for any length of time, may be looked upon as an evidence of disease; hence, they may be regarded as the indices of health. They comprise the following principles:—*colouring matter of the bile and urine, bilin, urea, uric acid, hippuric acid, uric* or *xanthic oxide, cystin* or *cystic oxide, kreatine, kreatinine, inosynic acid,* and *kiesteine.*

The colouring matter of the bile, and bilin, will be fully described under the head of the Secretion of the Liver; the other products under that of the Secretion of Urine.

II. The Non-Azotized Organic Constituents.—This group comprises three classes, the Saccharine, the Oleaginous, and the Acids.

1. *The Saccharine principles.*—Two varieties of sugar are found in the animal economy,—lactine, or sugar of milk, and glucose, or sugar of grapes, or diabetic sugar.

Sugar of Milk—Lactine.—This is a principle peculiar to the

secretion of the female mammary gland; it has not been discovered in the blood, hence it must be regarded as the product of cell-formation; but it has been lately asserted to have been noticed in a milky fluid discharged from an abscess in a nursing woman. It has also been shown to be a product of the egg in incubation, consequently it may be the result of transformation of other substances. Lactine is obtained by evaporating whey; it is in white prismatic crystals, very soluble in water, especially if hot; but does not form a syrup like cane-sugar; it is insoluble in alcohol, and does not undergo the vinous fermentation. It is converted into glucose by the catalytic action of the acids, especially hydrochloric, sulphuric, citric, and acetic. By a ferment it is converted into lactic acid; in this way, milk is caused to turn sour by the spontaneous fermentation of its sugar through the agency of the caseine. Its composition is $C_{12}H_{12}O_{12}$. It would seem that lactine might be formed out of the nitrogenized principles of the tissues, since it occurs in the milk of the carnivora.

Glucose — Sugar of Grapes — Sugar of Diabetes. — This principle may be produced by the action of dilute sulphuric acid upon cane sugar, sugar of milk, starch, or lignin,—the acid acting by *catalysis.* In vegetables, the conversion of starch into glucose by the agency of diastase is familiarly witnessed in the germination of seeds, and in the malting of barley. Glucose is a white, imperfectly crystalline substance, less sweet than cane-sugar, and not so soluble in water. It very readily undergoes the vinous fermentation,—being, in fact, the only variety of sugar which is susceptible of this process, the others being first transformed into it. Its composition is $C_{12}H_{14}O_{14}$.

It is difficult to discover glucose in the blood, for the reason that, in the healthy state of the system, it is broken up, as soon as formed, into lactic acid and the lactates, the lactic acid being in its turn very speedily decomposed into its ultimate elements for the purpose of affording the requisite hydro-carbon for the production of animal heat. According to Bernard, the blood of the right side of the heart, of the ascending cava, and of the hepatic

veins, always contain grape-sugar, no matter upon what the animal has been fed.

The *origin* of glucose in the animal economy is clearly traceable, partly at least, to the saccharine and amylaceous matters of the food. It has been already mentioned, when treating of *Salivin*, that in digestion the starchy elements of food underwent a change through the agency of this peculiar principle of the saliva, by which they are transformed into glucose, and so rendered soluble and capable of being absorbed. Dr. Price injected glucose into the veins of a dog, but failed to detect it in the urine; he repeated the experiment with cane-sugar, with the result of always finding the latter in the urine. If the cane-sugar was first swallowed, so as to undergo digestion, it did not appear in the urine.

Bernard's recent experiments clearly establish the fact that glucose is also produced, in considerable quantities, by the liver. He was led to investigate the matter from the fact that in many cases of diabetes mellitus, sugar continued to appear in the urine, notwithstanding the exclusive use of azotized food. As the result of numerous experiments on animals, fed upon an azotized and a non-azotized diet, for several weeks, he found sugar invariably in the liver, and also in the blood, but only of the hepatic vein, the ascending cava, and the right auricle. In the case of an executed criminal, who was perfectly healthy, the liver, examined the day after death, contained more than an ounce of diabetic sugar. He has also constantly detected its presence in the livers of different animals procured from the shambles.

Bernard is further of the opinion that the sugar is produced in the liver by a true secretion, since a slight galvanic shock, or irritation of the knife to the medulla oblongata at the point of the origin of the pneumogastric nerve, caused an increase of the sugar, so much so, that a large quantity was carried off in the urine, in the course of a few minutes. A very violent shock, or cutting through the nerve, will arrest the secretion altogether. In general, animals fed upon amylaceous matters produce more sugar than those fed exclusively upon nitrogenized substances; and the longer abstinence is prolonged, the less the liver secretes. As a

still more positive proof of its presence being due to the liver, it is stated that it can be detected in that organ of a fœtus, after the fifth month; and even in the liver of the fœtus of oviparous animals which are separate from the mother.

Various causes were found to arrest this secretion, such as any lesion of the nervous system producing acute pain, except irritation of the olivary bodies, which, as before mentioned, increases it. Certain diseases have a similar effect, especially such as exhaust the nervous energy; hence it may happen, that during the last stage of diabetes, the urine may be free from sugar, and the liver, after death, present but a slight trace of it.

As regards the question of what becomes of the sugar, whether formed from alimentary substances, or secreted by the liver, it can be traced in the blood only as far as the lungs, where it undoubtedly undergoes decomposition, through the agency of the oxygen inspired.

The animals experimented upon by M. Bernard exhibited evidences of great excitement, being in constant motion; their respiration was also notably accelerated. This continued so long as sugar could be discovered in the urine, and is explicable by the extra duty the lungs had to perform in destroying so large a quantity of sugar. This may possibly account for the liability of diabetic patients to pneumonia and phthisis, which are so often the cause of their death. The disappearance of the sugar in the lungs is a purely chemical act, and not dependent, as its secretion, upon nervous influence; since, if both pneumogastrics be cut, and glucose be injected into the blood, it was still consumed as before. Moreover, sugar in blood disappears when in contact with air, out of the body, as well as in the lungs; but it is necessary that the blood should be alkaline, as the presence of an acid prevents its destruction. Mialhe and Liebig ascribe it to the presence of the alkali, but M. Bernard, though admitting that the usual alkalinity of the blood favours its consumption, believes that it is chiefly owing to some peculiar ferment (a catalysing body), which he has not yet been able to detect, but which acts by converting the sugar into lactic acid and carbonic acid; the latter being thrown

off by the lungs, and its amount being always in proportion to that of the sugar.

In healthy urine, sugar is never observed, but in *diabetes mellitus* it appears in very large quantities in the secretion. The pathology of this disease is yet very obscure; the kidney is certainly not in fault, for the sugar has pre-existed in the blood; the difficulty appears to be either in the excessive production of sugar from the food, or more probably in a want of due assimilation of this principle. According to Mialhe, the non-conversion of the sugar into lactic acid is owing to a deficiency of alkalies in the blood; but it is not the alkalinity of the blood which destroys sugar, but rather the oxygen. As just mentioned, much of it is to be ascribed to the hepatic secretion. In the treatment of diabetes it is important to restrict the patient either to an exclusively animal diet, or to such vegetable substances as furnish no starch or sugar. Sugar has, however, been found, as previously mentioned, in the urine, even when an exclusive animal diet had been employed. It probably originated, in such cases, from the metamorphosis of some of the animal tissues. It is known that the glycocoll of gelatine will yield urea and glucose by the rearrangement of its elements; but it has not yet been clearly proved that this transformation actually occurs in the economy.

The following are the best tests for sugar in the urine. *Runge's test.*—Evaporate a small portion of the suspected urine on a porcelain plate, and drop upon the dry, warm residue a few drops of sulphuric acid diluted with six parts of water; if sugar be present, it will assume a dark brown or black colour. This is a very delicate test; but if albumen be present this must be previously removed, since it gives a similar colour with the acid. *Trommer's test.*—Add to the suspected urine, in a test tube, a few drops of a solution of sulphate of copper, then a solution of potassa in excess, and boil the mixture; the oxide of copper at first precipitated, is redissolved by the excess of the alkali, the liquid becoming deep blue; and if sugar be present, an orange-red precipitate of the suboxide of copper falls; if no sugar be present, the precipitate is almost black. A modification of this test is the

double tartrate of copper and potassa, known as the "liqueur de Barreswil." The proportions are, carbonate of soda and caustic potash, of each ℈iv, cream of tartar ℈v, sulphate of copper ʒj; distilled water Oj; to be boiled and filtered. A few drops of this liquid will produce, with a solution containing glucose, a reddish-yellow colour. *Christison's test.*—Evaporate the urine to a syrupy consistence, and add yeast, and set it aside in a moderately warm place. Vinous fermentation soon ensues, if sugar be present; every cubic inch of gas given off, corresponding, in round numbers, to one grain of sugar. This test detects one part of sugar in one thousand of urine. *Moore's test.*—Boil the suspected urine with an excess of liquor potassæ, when, if sugar be present, it will assume an orange-yellow, brown, or claret colour, in proportion to the quantity contained, owing to the conversion of the sugar into melassic acid. Heller states that, if an excess of nitric acid be now added, a strong odour will be developed in the sugar.—There are several other tests of inferior value.

2. *The Oleaginous Principles.*—These may conveniently be considered under the two divisions of *Saponifiable* and *Non-saponifiable Fats.*

The fatty principles of animals have only within late years received the attention which they deserve from their importance in physiology and pathology. They all contain a large amount of carbon and hydrogen; they are insoluble in water, partially soluble in cold alcohol, very soluble in boiling alcohol, and ether. Fats or oils exist both in vegetables and animals, varying in consistence from a perfect solid to a perfect liquid. When pure, they are tasteless and inodorous; they owe their flavour to a volatile principle which frequently derives its peculiarity from the food, as is witnessed in the butter procured from the milk of cows fed upon peculiar kinds of grass.

Saponifiable fats.—These are so named from their forming soaps with alkalies. They consist of a fatty acid united with a fatty base; hence, when presented to a stronger alkali, they are decomposed, their acid uniting with the alkali to form a *soap*, and

their base being thrown off; with a metallic oxide they form *plasters.* The non-saponifiable fats are not thus decomposed. In animals, these fats exist both in the free state, as in common adipose tissue, and in certain tumours; and also combined with bases.

The most important of the free fats are *stearine, oleine, margarine,* and *butyrine.* They are deposited in a crystalline state from their alcoholic solutions. Each of them consists of a peculiar acid (named respectively from the principle which furnishes it, as *stearic acid, margaric acid,* &c.), and a base which is common to all, called *glycerine;* hence it is the *acid* which gives the character to the different fats.

The consistence of the fatty principle varies; the fusing point of stearine is about 130° F.; that of margarine 116°; that of oleine 24°; that of butyrine 22°. Human fat consists of margarine and oleine, and is of a semifluid consistence during life; beef and mutton suet are composed almost exclusively of stearine, and are very firm and solid. The vegetable oils contain no stearine, with the exception of the fixed oil obtained by expression from the cacao beans, and known as *cacao-butter.* Palm oil yields a somewhat similar principle, called *palmitine,* and one is also derived from the cocoa-oil.

The several fat acids just alluded to exhibit all the properties of true acids, neutralizing bases, &c.; in the healthy animal economy, they always exist in combination with glycerine. *Glycerine* is procured in the process of saponification;—it remains in the mother-liquor. It is a viscid liquid of a sweetish taste, of a light straw-colour, incapable of fermentation. From its strong tendency to resist the drying process it has been used with advantage as a remedy in certain cases of sore-throat and deafness; also in obstinate cutaneous affections. Berzelius considers the true base of the fats to be the *oxide of lipyle,* the formula for which is C_3H_2; and that glycerine is a product of saponification, consisting of two equivalents of the oxide of lipyle added to three equivalents of water; thus, $2\ (C_3H_2O)+3\ HO=C_6H_7O_5$ (glycerine).

Origin of Fats.—Vegetables certainly produce fatty principles,

by their organizing processes, from starchy and saccharine materials. We have sufficient evidence of this transformation in the gradual disappearance of fecula, and its being replaced by oil in the castor-oil bean, in the flaxseed, and in the sunflower seed; also in the sugar-cane, where the sugar is gradually displaced by wax. This metamorphosis in living plants is accompanied by an elimination of oxygen. Fat (butyric acid) has also been artificially formed from sugar by the action of caseine, at a high temperature.

There is some difference of opinion in regard to the question whether animals have the power of producing fat, or whether they receive it already formed from vegetables. Mulder, Liebig, and other high authorities, assert that animals do possess this power, and that the process is essentially similar to that of vegetables. Numerous experiments were made to settle this question by fattening various animals on different vegetable matters, as peas, beans, potatoes, &c., the result of which was, that the animals gained far more fat than was contained in the food they had consumed; and in a cow which had been fattened upon grass, it was found that the fæces contained quite as much fatty matter as had been proved by analysis to exist in the food; consequently, the increase of the fatty tissue must have been due to some transformation in the animal system. M. Persoz found, in fattening geese, that the fatty matter formed in their bodies was more than double the amount that could be extracted from the maize consumed. Besides, animals contain peculiar fats, such as stearine, spermaceti, caproin, &c., which do not exist in vegetables; and, finally, it has been proved that bees fed upon sugar exclusively were able to form wax, a species of fat.

The theory of Liebig, also adopted by Dr. Chambers, is that the additional supply of fat, over and above what is received in the food, is due to the transformation of the ternary principles—starch, sugar, gum, &c., by deoxidation. Boussingault farther ascertained that geese fed upon nitrogenized matter, as pure caseine or albumen, had more fat upon them than could have been taken into their stomachs. Dr. Chambers supposes the conversion of

both the azotized and non-azotized principles into fat to occur in the intestines previous to absorption; but this, according to M. Bernard, is impossible, since the lacteals (whose exclusive office appears to be to absorb the fatty matter of digestion) never exhibit any traces of fat, unless it had first been administered by the stomach. From certain recognised pathological facts, such as the fatty degeneration of the liver, found in phthisis and in drunkards, as also in the enormous increase of fat in the livers of geese, when these were prevented from consuming their fatty tissues, Bernard was naturally led to look to that organ in searching for the explanation. As in the case of sugar already mentioned, so he discovered fat in abundance in the hepatic veins, and likewise in the liver, but could not find it in the portal vein. Hence he inferred that, in addition to the elaboration of sugar, the liver also produced fat. He likewise proved that it was chiefly, if not exclusively, during the act of digestion that the liver performed this newly-discovered office.

Hepatic fat differs somewhat from other varieties: it most resembles butyrine. It is sometimes found in great abundance in women during the period of lactation; and, as suggested by Bernard, this may be the source of the fat of the milk secreted by the mammary gland. The milky appearance noticed occasionally in the blood, known to be due to the presence of oily matter, is also probably to be ascribed to this source. On still farther pushing his researches, Bernard found that the arterial circulation exhibited the presence of fat, while none could be discovered in the venous (except the hepatic); the conclusion naturally followed, that it disappears in the capillaries to be deposited in the adipose tissue.

It is remarkable that there should exist a direct antagonism between the production of hepatic sugar, and hepatic fat: while a puncture of the medulla oblongata, at the origin of the pneumogastric nerve, notably increased the former, it invariably arrested the latter. In confirmation of this it is stated, that while the liver of a diabetic patient, who had died suddenly, contained seven grammes of sugar, no trace of fat was discoverable. As if

more completely to confirm these views of the origin of fat in the human body, it has been ascertained that, in the disease called *chylous urine*, fatty matter resembling butter is found in the urine, the secretion being doubtless owing to some derangement of the liver, which produces more than can be consumed, the excess passing off by the kidneys precisely as in the case of diabetes mellitus; hence, M. Bernard has given to that disease the appropriate name of *a fatty diabetes.*

Another source of the production of fat in animals, of a pathological character, is the degeneration of the proteine tissues—a fact first noticed by Persoz in the fattening of geese; in which he observed, that a large amount of oily matter existed in the blood at the expense of the albumen. Mr. Paget has lately shown that a similar degeneration exists in the human subject, constituting one form of atrophy of the muscular tissues, which will be noticed more at large subsequently. It has long been known that bodies, after having been buried in certain soils for a length of time, are found converted into *adipocire*, a substance resembling spermaceti; and this same change, according to Blondlot, may, at any time, be produced in albumen, simply by the agency of moisture, and a partial exclusion of oxygen.

It may be interesting to trace the progress of the fats through the animal economy. Constituting as they do a considerable portion of the food, they of course must pass into the stomach; here, however, they entirely escape the solvent action of the gastric juice, which appears to be designed exclusively for the albuminous materials of the food; they pass, then, unchanged into the duodenum, where they are acted upon by the bile and pancreatic juice, and are converted into an emulsion—a condition peculiarly favourable for their absorption into the lacteals. These points are all satisfactorily established by the experiments of Bernard. This physiologist noticed, that in the duodenum of the rabbit, the orifice of the pancreatic duct was several inches below that of the hepatic duct; and that, in this animal, no chyle was ever observed in the lacteals until the oily matter, which had passed through the stomach, had passed the pancreatic opening, when it imme-

diately put on the peculiar appearance of chyle. Bouchardat's experiment of feeding dogs upon the oil of sweet almonds appears to establish the fact that fatty matters undergo no chemical change in the upper part of the alimentary canal; for, on killing the animal a few hours afterwards, and testing the chyle with ether, the oil was separated in an unchanged state. After a hearty meal, of food rich in oily materials, the serum of the blood has a milky aspect, due to the presence of fat, as proved by its being dissolved by ether.

Admitting, then, that the fatty matters reach the blood, they must be disposed of in one of two ways: *first*, by undergoing decomposition so as to furnish the materials for producing heat; *secondly*, by being secerned into the adipose tissue, so as to constitute the fat of the animal. The *adipose tissue* is quite distinct from the areolar, with which it is intimately associated; it is composed of an aggregation of compressed, polygonal, nucleated cells, consisting of two coats, the interior one of which has a specific character, and differs from the exterior in not being soluble in acetic acid. The fat-cells may be either scattered throughout the areolar tissue, being held in their place by fibres, or else collected in small clusters, and covered by a common envelope, on the outside of which the blood-vessels ramify. This last is the proper adipose tissue. Each of these masses of fat-cells resembles a gland, except that there is no excretory duct,—the secretion being stored away instead of being thrown off. The fat-cells undoubtedly possess the power of modifying the material which they secrete, since we find that animals secrete fats quite different from those which enter into the composition of the food; thus, human fat contains little or no stearine, although this is largely consumed as food.

Hunter denied that fat should be considered as a proper tissue of animals, inasmuch as it may all be dissolved out of the areolar mesh by ether, leaving that tissue unaltered. He regarded it rather in the light of *fuel* stored away for an emergency, in case of failure in the food to supply the usual materials for heat.

Physiological Uses and Offices of Fat.—These are various: as

mechanically to protect the body and the internal organs against injury from pressure, falls, or blows;—thus, in wasting diseases, bed-sores are of frequent occurrence, from the absorption of the fat from the parts of the body exposed to pressure. It serves, also, as a non-conductor of heat, preventing the escape of caloric from the body; hence all animals inhabiting the polar regions are loaded with fat. But its most important use is to furnish the combustible materials for the production of animal temperature; and this it is peculiarly fitted to do, from the large amount of carbon and hydrogen which enter into its composition. Accordingly, we find the adipose tissue the first to disappear in the process of starvation, or in exhausting and protracted diseases. The oxygen, which is constantly introduced by respiration, attacks with avidity this tissue, combining with its carbon and hydrogen in the ultimate molecules of the body, giving out heat, as the result of the combustion; after which they are thrown off from the system in the form of carbonic acid and water. Now, when all the fat has disappeared, the oxygen attacks the proteine tissues,—since heat must be furnished somehow to the body; hence the mucous membranes suffer from a disintegration of their epithelium, as is constantly witnessed in the sore-throat and diarrhœa in the last stages of phthisis; and also in the mucous membrane of the stomach.

It is not well understood how the fat can escape from the adipose tissue, when required for the process of calorification, since the moisture which surrounds the fat-vesicles would interpose a resistance. It has, however, been shown by Matteucci, that oleaginous particles will pass through animal membranes, by endosmose, to diffuse themselves through an aqueous liquid, provided the latter is alkaline.

Liebig has constructed a table of food in reference to its power of producing heat up to a certain point; thus, taking fat as the highest on the list, he found that forty parts of it would produce the given temperature; next in order is alcohol, of which fifty-three parts were required; next starch, ninety-seven parts;

then cane-sugar, one hundred parts; glucose, one hundred and six parts; muscular flesh, three hundred and nine parts.

The importance of a proper temperature to animals can scarcely be overrated. The division of animals into the two classes of *warm-blooded* and *cold-blooded* is founded upon their capacity of maintaining a uniform temperature of about 98° to 100°, independent of the surrounding medium. In man it is indispensable that the normal temperature should be maintained to insure the fundamental action of the economy—the conversion of the common organizable material into the special plasma for each individual organ. Should the temperature of the body be persistently reduced a few degrees below this by any causes, as impoverished diet, insufficient clothing, and exposure to cold, the condition of the individual is necessarily degraded to that of one of lower organization; and, as a consequence, he will be liable to scrofula and other forms of disease connected with defective nutrition. From experiments made by M. Chossat on the starvation of animals, it is clearly proved that the *immediate* cause of death in such cases is cold,—a very considerable depression of temperature occurring just before the animal expired. He further showed that if, under such circumstances, the animal was placed in an elevated temperature, life would be prolonged for some time, even without food. The same condition exists, to a certain extent, in all wasting and protracted diseases;—there is either a loss of the normal animal temperature from the consumption of the fat, or it is maintained at the expense of the proteine tissues. In all such cases it is of the greatest importance that the clothing of the patient should be sufficiently warm,—a point very often practically neglected. There is an instinctive desire in the inhabitants of all very cold climates for a diet abounding in fat; this is well exhibited in the fondness of the Esquimaux and Greenlander for whale-blubber. Those living in tropical climates, on the other hand, are disgusted with such a diet, and live chiefly upon fruits and vegetables, or a light animal regimen.

A fourth physiological office of fat is to effect the solution, and consequent removal from the system, of morbid products of the

proteine type. Lehmann ascertained that albumen and caseine underwent solution when placed in contact with fatty bodies along with sugar,—the latter being converted into lactic acid. From this the inference was drawn that morbid structures in the living organism might be removed, and that thus fatty matters might prove valuable therapeutic agents. With this view *cod-liver oil* has been very extensively employed in various chronic diseases, especially tubercle and scrofula. It possibly acts only by supplying the calorifacient elements, in large quantities, to the system.

Pathological Conditions of Fat.—The most important one is that first noticed by Dr. Allison, consisting in a morbid accumulation of fat as the result of a true degeneration of the proteine tissues,—more especially the muscular; it also occurs in the nervous tissue. Mr. Paget has satisfactorily shown, that in these cases there is no true *secretion* of fat from the blood, as in ordinary obesity, but an actual transformation of the other tissues, which become soft, pale, and flabby. A similar condition is sometimes observed in cattle which have been artificially fattened; the animal becoming loaded with a semi-fluid diffused fat, which occupies the place of the natural muscular tissue. It is frequently noticed in the internal organs of the human subject, especially in the liver of drunkards, producing what is called the *fatty liver*, in which the organ is much enlarged, and the true bile-cells are filled up with fat. Next to the liver, the heart is most frequently affected; and next to this, the kidney. This same fatty degeneration also occasionally occurs in morbid structures, as cancer-growths, which, in this way, may sometimes be removed. Mr. Paget has farther shown that there is a remarkable disappearance of the *tissue-germs* or nutritive centres (nuclei) wherever such a degeneration is going on. This accords with the well-known physiological law, that the nutritive functions are active only in the immediate sphere of these germs. It is believed that this degradation of structure is owing to a deficiency of oxygen, preventing the usual results of the conversion of the proteine tissues into urea, uric acid, &c.

The fat thus pathologically produced differs from healthy fat in

being diffused, and not contained in cells; the muscles, also, are brown and soft. When morbid structures become the seat of this change, their further development or growth must of course be arrested; hence it may happen, as in some rare instances of cancer, that such a change may result in their cure, by rendering them capable of absorption.

Another pathological condition of fat is *obesity*, or *polysarcia*, which is a true hypertrophy of the adipose tissue,—the other tissues retaining their healthy condition. Obesity may be considered to exist whenever there is a disproportionate increase in the weight over the height. The established law of this proportion is, that from 5 feet 1 inch, up to 5 feet 11 inches, there should be an increase of 5½ pounds for every inch. There are also some few cases, where the excess of the increase is due to true muscular development, as in the instances of pugilists, whose muscles were under constant training. If obesity occurs in very early life, before puberty, observation has shown that the individual is not apt to survive that period; and if it occurs after this, the life is seldom very long.

The causes of obesity are not very well understood. Whenever the food contains a larger amount of carbon and hydrogen than can be acted upon by the oxygen of respiration, fat is apt to accumulate. Hence, it is a result of great digestive powers with a deficiency of oxygen.

The consequences of obesity are:—1. Its influence upon the circulation. Wherever there is hypertrophy in the system, there is always a larger development of capillaries at that point; and this is necessarily attended with a withdrawal of blood from other parts of the system, since the whole quantity of the circulating fluid is not increased. Hence, as the capillary area is very much enlarged around the adipose tissue, the arterial and venous areas diminish proportionally; this gives rise to the small pulse usually noticed in such persons; depletion is badly borne by them, fainting ensuing from the loss of a very small quantity of blood. 2. Its effects upon the respiration. The oppression and difficulty of breathing, consequent upon exertions in very fat persons, are

matters of common observation. Mr. Hutchinson has proved, by means of the spirometer, that the vital capacity of the lungs, in such cases, is remarkably deficient, being reduced in some instances from 200 cubic inches as low as 70. 3. The mere increase in the weight is the source of great difficulty, on account of the necessary increase in the expenditure of power on every exertion; hence, the slightest exercise proves fatiguing, and even the ordinary movements of the body draw off dynamic forces, which are requisite for the interior movements of the body. There are other results of obesity, of a pathological character, which are not, however, very clearly made out.

Non-saponifiable Fatty Matters.—These comprise only two principles, Cholesterine and Seroline.

Cholesterine was first discovered in the bile, whence it derived its name. It exists in healthy bile in very small quantities, but is much increased in disease, and deposited in the gall-bladder, constituting the chief ingredient of *gall-stones.* It has also been found in minute quantities in the brain, spinal marrow, blood, dropsical effusions, and in certain morbid structures, as tubercle, cancer, and fungus. It has not been discovered in vegetables, except in the resin of the pine (Dumas); hence it must be considered as a true animal product; and it is formed in the animal system, according to Mulder, by the deoxidation of margaric acid. Its formula is $C_{36}H_{32}O$. It is soluble in boiling alcohol, from which it is deposited in brilliant lamellæ of a pearl colour. With nitric acid it yields *cholesteric acid.* It will not form soap with the alkalies; but, in other respects, it resembles stearine and margarine. Its fusing point is 278°.

Seroline is a fatty principle peculiar to the serum of the blood; it forms pearly scales, which fuse at 98°. It is soluble in hot alcohol, from which it is deposited on cooling; also in ether.

3. The Organic Acids.—These comprise the Lactic, Oxalic, and Acetic acids.

Lactic acid exists, according to Berzelius, in the blood, and in the urine; this is, however, denied by other chemists. Liebig has found it in the juice of muscular flesh. He supposes that

lactic acid, and the lactates, are constantly forming in the blood from the saccharine and amylaceous articles of the food; and he further considers this acid to be one of the great supporters of animal temperature,—the fatty principles also contributing, as was mentioned before. The reason why it is so difficult to detect this acid or its salts in the blood is because they immediately undergo decomposition into their ultimate elements, furnishing carbon and hydrogen to unite with oxygen, to maintain heat. Liebig cites, in proof of this doctrine, an experiment of his own: he administered lactate of potassa to an individual, and detected none of the lactic acid in the urine, although the potassa was easily recognised.

Lactic acid exists also as one of the acids of the gastric juice; occasionally it would appear to be the exclusive acid of the stomach, though again it seems to be entirely wanting. It is a colourless fluid, soluble in water and alcohol. Its composition is $C_6H_5O_5+HO$,—which is nearly identical with that of starch and sugar.

Oxalic acid.—This is not a natural constituent of the animal organism, but is occasionally met with as a result of morbid action; in combination with lime, it constitutes a variety of urinary calculus, called the *mulberry calculus.* It is supposed by some to originate from sugar, or from certain articles of food,—just as it is formed out of the body; others ascribe it to the metamorphosis of uric acid and urea.

Acetic acid exists in the gastric juice, also in the sweat, milk, urine, and in the bullæ of pemphigus. It is a constant product of animal and vegetable putrefaction by the acetous fermentation, and is probably the most widely diffused of all the vegetable acids.

SECTION IV.

INORGANIC CONSTITUENTS OF ANIMALS.

Although animal tissues and organs are composed essentially of organic principles, the presence of certain inorganic materials

is indispensable for the perfection of their functions. These inorganic constituents are comprised under the three divisions of Liquids, Solids, and Gases.

I. Liquids.—Of all the liquids, *water* is by far the most important; it is water, in fact, which imparts the liquid condition to all others. Its universal importance in nature might be inferred from its almost universal prevalence over the globe,—two-thirds of the earth being occupied by water, and every cubic foot of air containing five or six grains of water. Regarded by the ancients as one of the four elements of matter, it may, even at the present time, be considered in a certain sense an essential element of all organized matter. No animal or vegetable can display vital actions without a due supply of this liquid. If deprived of moisture, the mosses and hepaticæ—among the lowest of vegetable productions—become completely dried up; but they may be made to resume their verdure on being moistened. In like manner, the *rotifera*, or wheel-animalcule, may be dried upon a piece of glass, and so preserved, apparently dead, for any length of time; but, on being moistened, it will become as active as ever. Many of the animal tissues depend upon the presence of water for the ability to display their peculiar properties and functions; thus, a piece of artery, or any other elastic tissue, if dried, entirely loses its elasticity, shrinking up and becoming like horn; the cornea, when dried, becomes opaque; cartilage, when thoroughly dried, loses all its elasticity, becoming hard; but on the simple addition of water, they all recover their original condition.

Water constitutes by far the largest part both of animals and vegetables. There are certain animals, as the jelly-fish, which seem to consist almost exclusively of water; one of these weighing, fifty pounds, has been dried down to a weight of only as many grains. The same is true, to a great extent, of the human body, judging from the weight of the dried mummies of Egypt, which do not exceed 15 or 20 lbs., and in one instance amounted to only 7 lbs. Water, in fact, constitutes upwards of 90 per cent. of the human body.

Physiological Relations of Water to the Economy.—The proper

quantity of this liquid necessary for the whole system, and also for its various tissues and organs in health is fixed and definite; any considerable departure from the standard will constitute disease. As already mentioned, it is essential to the mobility and elasticity of the different parts of the body. Again, it is the great solvent of the system; nutrition could not be accomplished without the materials of the food being first reduced to the fluid state so as to be absorbed, nor could the products of the waste and disintegration of the tissues be eliminated from the body, without first being dissolved, so as to pass into the various excretions.

Water constitutes about 99 per cent. of most of the animal fluids, and upwards of 90 per cent. of many of the solids. Its quantity, however, varies in different tissues, abounding most in those whose vitality is most active, as in glands and mucous membranes, but being deficient in those of low vitality, as in bones and cartilages. It always is in excess whenever vital energy is the greatest; hence it abounds in infancy and youth, but diminishes as age advances, causing the shrivelled appearance so characteristic of old age;—death from old age is, in fact, the natural result of this gradual solidification.

In the state of *vapour*, water also exercises considerable influence upon the animal system. From the immense surface of water upon the globe, vapour is incessantly exhaling into the atmosphere, to the extent, according to actual calculation, of about sixteen tons in a minute. Its presence in the atmosphere is indispensable to comfort and health; if it be deficient, a dryness and feverish state of the skin is produced from too rapid evaporation of the perspiration, as witnessed in the Sirocco of the deserts; if in excess, the due evaporation from the surface is prevented, and the perspiration is restrained.

All the fluids of the body, whether moving or stationary, derive their very existence from water; thus it is indispensable to the circulation of the blood, as is seen in some cases of cholera, where the great loss of water causes the blood to become so inspissated as not to flow through the vessels. It is likewise the chief element of the secretions. From its chemical indifference to most bodies,

it is peculiarly adapted for a general solvent, since it can hold in solution, at the same time, many substances chemically opposed to each other; the blood affords a striking example of this, and it is, in consequence, enabled to place these different principles at the disposal of the various parts of the organism, just as they are required. In the same manner many exterior bodies may be taken up by the blood and brought into contact with the different tissues and organs; thus medicinal agents produce their effects upon the economy.

The due supply of water for the living organism is of too great importance to be intrusted to the *will* of the animal. It is forced to receive the requisite amount by the most imperative of all the organic senses—*thirst*. This sense, although apparently seated in the fauces, is in reality the expression of a general want felt throughout the whole system.

Chemical Relations of Water.—It combines with bodies chemically in definite proportions, both as a base and as an acid; in the latter condition it constitutes *hydrates;* most of the constituents of the blood exist as hydrates. Again, it undergoes decomposition, its elements, hydrogen and oxygen, exerting the most powerful affinities in their nascent condition; it may thus at one time oxidize, and at another deoxidize,—the hydrogen at the same time combining with nitrogen to form the amides, or ammonia; an example of such changes is afforded in the transformation of uric acid into alloxan and urea (Liebig).

Animals obtain their water through their food and drinks. As found in nature it is seldom pure; even rain-water, generally considered the purest, frequently contains traces of ammonia; and that which first falls after a long drought, is largely impregnated with organic matters, and soon becomes putrid in consequence. Spring and well water always contain more or less saline matter, which they have derived in their percolation through the soil: these substances may be so abundant as to render the spring medicinal. The usual saline constituents of springs are the alkaline and earthy salts,—precisely the same as those which exist in the blood. The best spring water is that which has had a surface-

action over sand and clay, or that has percolated through granitic rocks with but a slight soil upon the surface. Some of the saline ingredients of water appear to be more essential to animals than others,—for instance, the soda salts; this may account for the universal instinct for chloride of sodium, the chief source of all these salts. Water also contains atmospheric air in solution; its presence in the water is requisite to render it at all palatable, as may easily be proved by its insipidity when deprived of the air by boiling. The air thus contained in water is richer in oxygen than the atmosphere,—containing 28 parts in 100.

The *hygienic relations* of water are of great importance, since it is so intimately connected with every action of the animal economy, and a due supply of pure water is so essential to health. If rendered impure from any cause, it may, and does often prove the source of endemic disease. It is a common observation that limestone water (water holding carbonate of lime in solution through excess of carbonic acid) often produces diarrhœas; the remedy here is very simple,—a piece of lime, which, combining with the excess of carbonic acid, precipitates the whole in the state of an insoluble carbonate. Disorders of the alimentary canal frequently follow the protracted droughts of summer, in consequence of the greater concentration of the solid ingredients in springs and wells. Another frequent source of impurity in river water is the damming up of the streams, and the erection of manufactories upon their borders; the stream should have a large extent of surface-action over pebbles and sand, by which it may be depurated of its impurities. In all cases it will be proper to filter such water through sand and charcoal, before using it as a drink.

Pathological Relations of Water.—As we have seen, there is a certain amount of water in the system in health. In disease there may be an actual increase, as in dropsy, or a relative increase, as in anæmia (spanæmia), or chlorosis, where the blood becomes impoverished through loss of its organic constituents. In such cases, if the individual be exposed to the causes of inflammation, as cold, there will be a great tendency to a sudden effusion of water through the weakened walls of the capillaries, often drown-

ing the lungs, and terminating life. We must not, however, forget that there is a natural difference in different temperaments as regards the normal amount of fluids; the lymphatic for example, containing more than the sanguine; and this fact should always be recollected in practice, since the former temperament will tolerate depletion much worse than the latter. In Asiatic cholera the water often is reduced as low as 530 parts in 1000, preventing the proper circulation of the blood. In this affection the real difficulty seems to be a loss of water, not only in the blood, but, in every tissue throughout the body, causing universal dryness of the tissues; this of course interferes with the due performance of the different functions, producing the suppression of the bile and urine, not because of any disorder of the liver and kidneys, but simply from the want of water to constitute these secretions. From the same cause, the nervous centres lose their power of generating and receiving impressions; hence the apathy and indifference of the patient to his situation; hence also the cramps of the muscles, which are not accompanied by motion, as in true convulsion. In cholera there would appear to be a loss of the power of endosmose in the intestines, since there is a constant leakage into them of the watery portions of the blood; for this reason no permanent benefit ever arises from injecting saline solutions into the veins, as was formerly practised; for, although for the time fluidity is restored to the blood, and the patient frequently rallies, in the end, the previous condition returns, and the case usually proves fatal. Serous diarrhœa differs from cholera very essentially in the circumstance of the intestines not losing their endosmotic power; consequently the collapse is far less frequent in that disorder.

As a therapeutic agent, water has been employed by the physician from the earliest ages. It is a remedy of great power, and one of extensive application; but liable also to great abuses in the hands of the empiric. The surgeon employs water with great benefit to wounds, and after operations, in the form of *cold water dressings*. The physician uses cold water with great success in all ardent fevers, both internally and externally, whenever there is great thirst, and a very hot and dry skin. The use of ice-cold

water, and often preferably of ice itself, seems to be instinctively demanded in such cases, as well as in acute inflammation of the stomach. This is especially true of certain conditions of excitement of very young children. Another admirable application of cold water is to the head, in inflammation or congestion of the brain. *Hydropathy* is a modern perversion of this excellent remedy. The practice is undoubtedly efficacious in many cases, but it is highly dangerous if improperly applied. It may be considered as safe so long as the temperature of the reaction *exceeds* that of the body before the application of the remedy; if it only equals it, it is of doubtful utility, and if it falls below it, it is positively injurious. The danger of its frequent application, even where there is a proper degree of reaction, is that the patient is debilitated from the constant succession of artificial fever thus produced.

II. The Inorganic Solids.—These inorganic constituents comprise the various salts which are contained in the blood and the different secretions; consisting of the *chlorides of sodium* and *potassium*, the *tribasic phosphates of soda, potassa, lime,* and *magnesia*, the *carbonates of lime* and *magnesia*, the *sulphates of soda* and *potassa*, and the *fluorides of calcium* and *silicon*. Also the metals *iron, copper,* and *manganese*, together with *sulphur* and *phosphorus* in the proteine-compounds. Some of these have already been alluded to; those which exist in the blood (the salines) will be fully described under that head.

III. Gases.—These are *oxygen, carbonic acid,* and *nitrogen*, all of which are contained in both arterial and venous blood, though in different proportions. Arterial blood contains the oxygen in excess; venous blood, the carbonic acid in excess; the nitrogen exists in nearly equal proportions in both. The atmospheric air inspired into the lungs is probably absorbed by the blood, just as by any other liquid; its oxygen is consumed by the various tissues in the capillary regions, from which, also, it receives its carbonic acid; the nitrogen remaining unaffected. This will be more fully noticed under the head of Respiration.

We have now completed the consideration of the *materials of organic matter*, under its different aspects, as originally proposed. We have noticed in succession its composition, its chemical actions, its two varieties of vegetable and animal matter, its origin, its conditions in living beings, and its two states of solid and fluid; in the next place we have considered its proximate constituents, which embrace four distinct groups of matter, all containing nitrogen; then followed the secondary constituents, comprising the azotized and non-azotized classes; and last of all, the inorganic constituents. We are, in the next place, to consider the different *forms* which these materials assume in the processes of life. Organic chemistry has been chiefly instrumental in revealing to us the materials; we are indebted to the microscope for the disclosure of the forms; and it is only within late years that the physiologist has been enabled to attain these true starting-points of his science, from which alone he can expect to push his investigations with any prospect of ultimate success.

PART III.

OF THE DIFFERENT FORMS ASSUMED BY ORGANIZED MATTER.

CHAPTER I.

PRIMARY FORMS OF THE ORGANISM.

MULDER observes that it is impossible to separate the *form* from the *material* in organized structure, or to say which has the precedence, so intimately are they connected. Every modification of material will cause a necessary modification in form, and this, in turn, will produce a difference in *function*. Every living organism must possess these three elements—material, form, and action, both in the healthy and the diseased structure. The common material out of which the entire organism is to be developed is crude albumen—it is variously named *plasma*, *blastema*, or *cytoblastema*. For each individual organ or tissue, this plasma is modified, so as to become a *protoplasma*, or special for that particular tissue or organ; and thus, as we have seen, it insures to it a special form. Although every organ has its own peculiar form, the general plan on which each is constructed is the same for the highest as for the lowest; it is moreover identical in both vegetables and animals, at least in the primary stages.

This uniformity in the early development of vegetable and animal tissues evidently demonstrates the existence of a constant cause or *force*, just as the constant occurrence of the different phenomena of inorganic matter, proves the existence of the various forces of gravitation, cohesion, magnetism, &c.; and to this force, presiding over organic matter, the term *vital force*, or *force of life*

has been applied, as before explained (Part I.); and the only mode by which it can manifest itself is by the development of organized forms out of a formless material. The primary organic forms consist of Granules, Nucleoli, Nuclei, Cells, and Fibres.

For most of the tissues the primary form is a germ or cell; for some few, a fibre. Some of the very lowest organic beings, both in the vegetable and animal world, never proceed beyond this primary form, consisting of nothing more than a simple cell, as is seen in the *Protococcus nivalis* or *red snow*, and in the *monads*. Even in the highest animals, a large portion of the tissues consists of only an aggregation of cells, as in the epithelial and glandular tissues,—each individual cell being, in its function, a complete epitome of the whole tissue or organ. In fact, all the organic or vegetative functions of living beings are performed by the agency of cells. Each cell is a distinct independent living organism, performing its allotted office, and then either dying out and giving place to its successors, or else remaining as a permanent part of the structure. Hence a proper understanding of the physiology of cells is indispensable to a correct knowledge of most of the functions of life.

The honour of establishing the cell-doctrine is generally attributed to Schleiden and Schwann, the former having first applied it to vegetables, the latter to animals. Raspail had, however, previously announced that the origin of both vegetables and animals was identical, viz., in a vesicle or cell.

In the development of the primary forms, a regular progression is always observed. In the first place, there must be a plasma or blastema; when this is placed "within the sphere of vitality," it is immediately observed to undergo a change; it loses its transparency, and becomes opaque from the presence of a very fine granular matter, or *organic dust*, which subsequently precipitates. This is well shown in the transparent glutinous matter effused after a cut, or after wounding a vegetable. The next step is the formation of larger granules, by an aggregation of the first, constituting *nucleoli* and *nuclei*, or germs; and it is highly probable that every germ is produced in this manner. The third step is the formation of

cells, which are believed to result either directly from the nucleus pushing out its walls on one side, which gradually enlarge so as finally to completely surround it, or from a precipitation of the fine granular matter around the nucleus, so as gradually to assume the form of a membranous envelope. Most cells exhibit a distinct nucleus; some are non-nucleated.

Although all the above steps of organization are usually observed in the development of the tissues, it would appear that *fibres* are sometimes formed directly from granules. The different primary forms will be now separately considered.

1. *Granules.*—These primary forms are constantly being produced in a healthy plasma, when within the influence of the germ-force, oxygen, and a proper temperature. By Henle they are termed *elementary granules;* by others, *organic molecules.* Mr. Paget states that every hypertrophied structure exhibits a large increase of them, whilst there is a deficiency in atrophy. They probably differ essentially among themselves in form and composition, although apparently identical; acetic acid will dissolve some, but leave others untouched. The granules of pus and mucus are said to be flat and depressed; others are round and oval. Their *size* also varies, being from 1-10,000th to 1-2000th of a line; requiring a microscope of extreme power to distinguish them. They perform two functions—the formation of a material by some modification (probably chemical) of the original blastema, and their own aggregation, by which the nucleoli and nuclei are generated.

Henle and Mandl supposed the granules to be nothing more than oil-globules surrounded by an albuminous coating; a view probably adopted from confounding them with the molecular base of the chyle, which really is of this nature; Ascherson also fell into the same error; but the one is evidently only an emulsion, whilst the other is the result of the presence of certain indispensable conditions, viz.: the germ-force, oxygen, and temperature, and a plasmatic material.

2. *Nucleoli* and *Nuclei.*—According to the theory of Schleiden and Schwann, the nucleolus is formed by the aggregation of the

granules, around which a precipitation of other granules takes place to produce the nucleus. In some instances the nucleus is apparently solid, in the interior of which the nucleolus lies embedded; in others, the nucleolus seems to thin away, causing the nucleus to appear more liquid and translucent. In some cases, the nucleolus is apparently formed subsequently to the nucleus.

The nuclei have not always the same shape; some being round, others oval, and others again granular. They are, no doubt, proteine-compounds; but in what peculiar manner they are modified, is unknown. The nuclei of each tissue are entirely distinct and specific as to their functions. The nucleus is never soluble in acetic acid, whilst the surrounding cell-wall is always soluble, or else becomes so thin as to be transparent.

The function of the nucleus, according to Schleiden and Schwann, is to form the cell, and then to disappear,—whence their name of *cytoblast*, or *cell-germ*. This is true in the case of many vegetables, but not of animals; in these the nucleus is of greater importance than the cell itself, because, while the latter may die out, the former is frequently persistent, and continues to furnish successive generations of cells. The nucleus is now regarded as the true seat of all the active forces of cell-life, as the catalytic action, or the *metabolic force* of Schwann; although this physiologist ascribes this force to the cell-wall. It is the disposing cause of all the subsequent changes which take place within the cell, for the further development of the tissues; hence it has been appropriately named by Paget, the "tissue germ." They always exist whenever a *form* is to be developed; but it will be remembered that themselves are always the result of a parent germ, which, in its turn, is probably composed of numerous granules.

In the *basement* or *primary membrane*—the foundation of all the epithelial structures, the nuclei are frequently visible as minute spots scattered over the surface. By Prof. Goodsir, they have been named "nutritive centres," or "germinal spots," from the function ascribed to them, which is to absorb the nutritive material from the blood, and to dispose of this to the parts sur-

rounding them. In this manner, the basement-membrane acts as the medium of the nutrition of the epithelial tissues.

The position of the nucleus in the cell varies; sometimes it is in the centre, at others in the side, and again between the two layers of the cell-wall. Several nucleoli are often contained within a single nucleus.

3. *Cells.*—A cell, in physiological language, may be defined to be a closed sac or vesicle, whose walls are composed of a delicate membrane, and containing a fluid, whose contents may be of a varied character. Its mode of formation has already been described,—either from an enlargement of a projecting membrane from the nucleus, so as gradually to surround the latter, or by a precipitation of the fine granules around the nucleus, in the form of a membranous sheath. The cell-wall usually consists of two membranes, which are differently affected by chemical reagents, proving that they differ from each other in composition. They can, moreover, be made to separate from one another by the action of a liquid, and, as already mentioned, the nucleus is often lodged between them. In the vegetable cell, the exterior coating consists of cellulose; but the interior one is always composed of a proteine compound. In animal cells both walls consist of a proteine substance, the exterior being probably fibrine, and the interior an oxy-proteine.

Schwann and Schleiden maintained that every cell must necessarily be formed from a nucleus. This is probably true for vegetables; but there are certain animal cells which are produced independently of a nucleus, as in those which are observed to form so rapidly in the early period of the ovum. The cell-wall, in such cases, is most probably formed from the granules which float in the material. After the exterior wall is formed, the interior of the cell becomes filled with granules, which precipitate around the inside of the envelope to form the interior wall. According to Schleiden, the vegetable embryonic cells contain no true cellulose; it is acquired, however, subsequently, so as to constitute its outer wall.

In the non-nucleated cells, it is probable that the inner cell-

wall possesses the usual properties of the nucleus, and that, in fact, it may be considered as the nucleus diffused. A cell may contain several nuclei, just as a nucleus may contain several nucleoli.

Cells multiply in several different methods. 1. By an independent formation, or by an original primordial generation, out of the organic molecules in the plasma. Examples of this method of increase are afforded of the plasma effused from a cut surface, in which numerous independent cells are soon observed to form. 2. By the *endogenous* method, or from within a parent cell. This method occurs frequently both in vegetables and animals; in the latter it is exhibited in the ovum before impregnation, when successive generations of cells are produced by this method, their function being, according to Barry, to work up and prepare the material of the egg for the future nourishment of the new being. The nucleus, when it exists, appears to perform an important part here; each one of its constituent granules becoming developed into a cell so as completely to fill up the parent cell. 3. By the *exogenous* method, from the outside of a parent cell; it is sometimes termed *sprouting*. This process never occurs in animals; in vegetables it is observed in the development of the yeast-plant, which increases by new offsets springing from the outside of the cell. 4. By *division*, or *segmentation*. Here the original cell splits up and divides successively into a great number of new cells; as is noticed in the ovum after fecundation, where the new germ-cell first divides into two, then each of these into two others, and so on, until a countless number are produced. It occurs also in cartilage.

Cells thus formed are disposed of in various ways in the living body. Some retain their independent isolated condition throughout their whole existence, performing, however, certain important functions,—as the corpuscles of the blood, lymph, and pus; others undergo transformation into new forms, as fibres; a third set remain as a permanent part of the structure which they have formed, as in the adipose tissue, cartilage, and bone; and a fourth class undergo a rapid development and disintegration, throwing out their contents in the act of dying out. These diffe-

rent results of cell life afford a natural ground of their classification into the following groups:

1. *Simple, isolated,* or *independent floating cells;* they comprise the red and white blood corpuscles, the lymph and chyle corpuscles, and the pus corpuscle. Each one of these is entirely distinct and independent of its fellows, both as to its origin and its function.

2. *Persistent cells,* or such as undergo no further change after being formed; these include (*a*), the aggregated, as the fat-cells; (*b*), those which are imbedded in a granular matrix, as the vesicular or gray neurine; (*c*), linear cells, constituting fibrillæ, as seen in the formation of the ultimate muscular fibril, which was formerly supposed to be a tubule; (*d*), cells imbedded in a material, which they have themselves formed both around and within them, as in cartilage, bone, horn, &c.

3. *Transitional,* or *metamorphosing cells,* or such as undergo transformations into new forms; examples are offered in the areolar tissue, when the fibres are formed by the elongation and splitting up of cells; it occurs also in feathers, in fibro-elastic tissue, in the fibrous exudation on serous surfaces in inflammation; it is likewise witnessed in the cancer-cell. In some cases, it would appear that an elongation of the nucleus precedes that of the cell. Schwann describes the formation of nerves as proceeding from an elongation of cells, which become tubules, in which the nucleus constitutes the neurine. A similar sort of development is generally believed to belong to the capillary system of blood-vessels; the first thing which can be observed in the vascular area of the embryo being a layer of cells; these soon send out prolongations on all sides, which, meeting with similar prolongations of other cells, coalesce with them, opening at the point of contact, and thus form a continuous network of tubuli. The nuclei are believed to become blood-corpuscles.

4. *Desquamating,* or *moulting cells,*—such as rapidly attain their growth and speedily die out, throwing off their contents; these include the epithelial, epidermal, and glandular cells. They constitute the true chemical apparatus of the organism.

4. *Fibres.*—It has been shown above how fibres may be produced by cells; but certain fibres are formed independently of cells, as by a direct coagulation of fibrin, as seen in the fibrillary arrangement assumed by coagulating blood; these latter ought consequently to be considered as belonging to the primary forms. Most fibres, however, are undoubtedly secondary in their formation, being produced, either from a cell, or from a nucleus, by elongation. The areolar tissue presents an example of both kinds, which may be distinguished from each other by the action of acetic acid dissolving the fibre which originated from a cell, but not affecting the other. In cancer-growths we find fibres produced in a similar manner, intermingled with the peculiar cancer-cells and granules.

The mode of production, functions, &c., of the *germ*, will be fully noticed under the head of Reproduction.

Pathological Changes in the Primary Forms.—From the foregoing consideration, it can be understood that the primary organic forms are the instruments or agents by which Nature accomplishes the building up of all the tissues and organs of the body. Not only does this take place in the normal condition, but it is equally manifested in the abnormal or pathological states; the same organic law of development presiding equally over both; the only difference being in the *material*, or plasma, upon which it is to operate. In all pathological growths, there is first an abnormal blastema, in which are developed granules, nucleoli, nuclei, cells, and fibres, just as in a healthy blastema; but of course, all these primary forms must be different from normal primary forms, since they are the result of an abnormal material. What constitutes this difference in the blastema we are unable to ascertain; to all appearance they appear perfectly identical, yet they must differ, because they give rise to different forms, according to the well-established law of the uniform agreement between material and form. The reason why we cannot push our researches into the nature of the original blastema, is because the development of the primary forms occurs *concurrently* with that of the various

protoplasmata: they are not successive acts, but both go on at the same time. In post-mortem examinations, we only witness the *results* of these changes: their beginnings must always elude our scrutiny. For this reason, mere pathological anatomy—which has reference only to these results, cannot be considered as the true basis of medicine; we must look beyond it to microscopic investigations, by which alone we can hope to unravel the more hidden and primary changes.

It has already been observed that cells constitute the aggregate of many of the organs of the body; whilst others consist of fibres—the result of the metamorphosis of cells; and others again of membranes which have resulted from fibres. Now, if any disturbing cause should interfere, so as to produce an arrest of the development of any one of these tissues, its function would, as a consequence, be interrupted. A few illustrations will make this matter clearly understood. The epithelial structure is composed of cells which are in a constant state of development from germs, and of rapid desquamation or moulting, by which process their secretion is thrown out. If, however, any disturbing agency be present, as an inflammation, their regular development is interfered with, and they are thrown off prematurely in a vitiated secretion; as is seen in the discharges of a chronic catarrh, in which no true epithelial scales can be distinguished, but only a great number of granules and corpuscles. So likewise in those tissues in which, in the normal condition, cells are developed into fibres; in disease an arrest takes place, and no further transformation of the cell occurs, but it retains its original embryonic condition, and such a structure appears to have actually retrograded to a lower state. This is well exemplified in *scrofulosis*, which is a constitutional disease, depending upon a defective plasma and a defective life-action. Now, if an individual placed under circumstances tending to deteriorate his plasma, as imperfect food, air, clothing, &c., be exposed to the common causes of inflammation, the result will probably be this arrest in the development of structure, which will retrograde to its original corpuscular condition. The scrofu-

lous structure is, however, a *living* one, undergoing the ordinary metamorphoses, but in a degraded condition. Hence, it is often curable by proper hygienic measures. Indeed, it often undergoes a spontaneous cure, as age advances, from the improved condition of the plasma. *Tuberculosis* is a lower grade of organization than scrofulosis; no *living* structure is produced in it, as in the latter. An attempt is made to form structure out of the defective plasma, but it never proceeds further than the cell, which dies out, aborted. Under the microscope, a piece of a very young tubercle exhibits numerous caudate nucleated cells, granules, and corpuscles, but no higher organic forms: it is not capable of further development. For this reason tuberculosis is incurable; the different deposits may undergo softening and removal, but the *condition* of system tending to produce them still remains. In *cancer*, the various primary forms of granules and cells are exhibited, imbedded in a large quantity of fibrous structure. The cells are generally of the caudate form (a shape at one time supposed to be peculiar to the cancer-cell, but it is seen also in the transitional cells which form fibres, and also in tubercle), which contain nuclei and nucleoli. The cancer structure is a living one; there is growth as in healthy structure, but there is wanting the *modality* by which it should be moulded after the peculiar type of the tissue; hence we have the same result in cancer growths, no matter what is the tissue in which they occur, whether in skin, glands, or bone. There must be some original difference in the cancer-germ, which causes it to take on this abnormal growth. How it gains an entrance into the system is not known; the belief that it is contagious is probably without foundation.

CHAPTER II.

SECONDARY FORMS OF THE ORGANISM, OR THE TISSUES.

FROM a diversified arrangement of the primary organic forms, described above, and as their immediate result, the *tissues* are

developed. These may be defined to be "the proximate anatomical elements out of which the organs are formed." An *organ* is "an instrument for the performance of a special function." A number of different organs united to accomplish one end, constitutes an *apparatus ;* thus, the digestive apparatus comprises several distinct organs, each of which performs its own appropriate function,—as the teeth, salivary glands, stomach, liver, &c., but all of which contribute to the same ultimate object—the digestion of the food. The combination of all the different apparatuses constitutes the *organism,* or *economy,* both in vegetables and animals.

A general knowledge of the tissues, or *histology* is important to the physiologist, since every organ of the body is composed of a diversity of tissues, and each one of these is peculiar as regards its material, vitality, function, &c., and likewise in its pathological conditions. Various attempts have been made to classify the tissues by different physiologists and general anatomists. Haller described only three,—the *Nervous, Muscular,* and *Cellular,* all the organs being formed either from a union of the first two classes, or by the last alone. Dr. Carpenter's arrangement is based upon their fundamental relation to the three elements,—*membrane, fibres,* and *cells ;* it is as follows:

a. Simple membranous tissues. Examples are rare in the human body : capsule of the lens, and posterior layer of cornea ; basement-membrane, and cell-walls.

b. Simple fibrous tissues. These include white and yellow fibrous tissue, and areolar tissue. Their use is to connect together different parts, and to associate the elements of other tissues.

c. Simple cells floating separately in the fluids, as corpuscles of blood, lymph, &c.

d. Simple cells developed on the free surfaces of the body, as epithelium and epidermis.

e. Compound membrano-fibrous tissues, composed of a layer of simple membrane, developing cells on its free surface, and united on the other to a fibrous or areolar structure ; as skin, mucous,

serous, and synovial membranes, lining membrane of blood-vessels, &c.

f. Simple isolated cells, forming solid tissues by their aggregation; as fat-cells, gray nervous matter, absorbent cells, cartilage cells, &c.

g. Sclerous or hard tissues, in which the cells have been more or less consolidated by internal deposit, or more or less coalesced with each other; as hair, nails, bones, &c. Its hardness is owing to the large proportion of inorganic material.

h. Simple tubular tissues, formed by the coalescence of the cavities of cells, without secondary internal deposit; as the capillaries.

i. Compound tubular tissues, containing a deposit within the cells; as in nerve tubes, and non-striated muscular fibre.

The classification of Professor Jackson is the one adopted in the present work. Its main divisions are founded chiefly upon their proximate chemical composition; the subdivisions, upon their functions.

CLASS I. Those composed of the proximate element *gelatine* or *chondrine;* their functions simply mechanical; their vitality low.

Order 1. Common connecting, or general tissue, termed *areolar;* it is universally diffused throughout the body, uniting the various tissues together.

Order 2. Lubricating, or friction tissues, termed *serous.* Their office is to diminish friction between moving surfaces. There are three species:—1, the splanchnic or visceral, as the peritoneum, pleura, pericardium, and arachnoid; 2, the synovial, lining the joints; 3, the angeal or vascular, lining the whole interior of the vascular system, and forming the capillaries almost exclusively.

Order 3. Sclerous, or hard tissues. Their office is to protect, bind parts together, and form levers. There are six species: 1, the fibrous—very generally diffused throughout the body, as the fascia of muscles, tendons, ligaments, dura mater, &c.; 2, the yellow or elastic tissue, a modification of the former;

employed to economise muscular power; examples are afforded in the middle coat of the arteries, ligamenta subflava of the spine, and the ligamentum nuchæ; 3, the cartilaginous; 4, the fibro-cartilaginous; 5, the osseous; 6, the corneous, as the nails and hair.

CLASS II. Those composed of a proteine, or oxy-proteine element; their functions organico-chemical; they perform all the chemical actions of the organism.

Order 1. The epithelial, consisting essentially of cells arranged upon a basement-membrane. There are five species: 1, the alimentary; 2, the respiratory; 3, the glandular; 4, the epidermoid; 5, the genito-urinary. Each one of these species might properly be subdivided into varieties, since the epithelium lining the different parts differs in several points, and performs different offices: in the mouth and fauces it is protective; in the stomach it secretes the gastric fluid; in the intestines it is also secretory. The glandular epithelium varies exceedingly from a simple crypt or follicle to the most complex and tortuous structure; as in the kidney and testicle.

CLASS III. Those consisting of fibrine; their functions organico-mechanical; they are instruments for performing the active motor offices of the economy.

Order 1. Sarcous, or muscular. There are four species: 1, the striated, found in all the voluntary muscles; 2, the non-striated, existing in the involuntary muscles; 3, the cardiac, found in the heart,—it is striated, but peculiar; 4, the uterine. Some add a fifth—the dartos of the scrotum, which seems to be intermediate between true muscle and areolar tissue.

CLASS IV. Nervous tissue, composed of a special organic complex element—*neurine*; function, organico-dynamic; it produces motion, sensation, and the psychological phenomena. There are three species: 1, the cineritious or vesicular—seen in the ganglionic centre of the brain and spinal marrow; 2, the gray or granular—found in the ganglia of the sympathetic nerve, the vesicles differing from those of the former; 3, the medullary or tubular—existing in the nerves and commissures; their function, internunciary.

The tissues will be next considered in the order above mentioned.

SECTION I.

TISSUES COMPOSED OF THE PROXIMATE ELEMENT GELATINE, OR CHONDRINE.

THE tissues comprised under this class possess but little sensibility in the healthy state, and their organization is comparatively low. The object of this is evidently to prevent the pain which would otherwise result from the performance of their common functions, exposed as they are to so many causes of injury. In inflammation they acquire very great sensibility, as is witnessed in inflammation of the pleura and peritoneum, and of the ligaments and fascia. It is difficult to explain how this sudden acquisition of sensibility occurs; no nerves can be traced into them in health; and it is hardly possible that sensitive neurine can be so quickly developed in them in disease. Although devoid of common sensibility, and of irritability (in the sense of Haller), they do possess the capability of reacting under an impression, since an offending agent will excite in them a vital reaction, resulting in irritation and inflammation. These tissues are not all equally irritable; the areolar, serous, and fibrous are most so; next in order follow the osseous, the cartilaginous, and the corneous.

A considerable part of the body is composed of simple fibrous tissues, in which the fibres are merely interwoven together, just as they are in the coagulum of inflammatory blood, or in the false membranes which are the results of inflammation. These fibres are solid, and have only *physical* powers, which serves to distinguish them from both muscular and nervous fibres, which are hollow, and possessed of *vital* properties. The simple fibrous tissues serve to bind together the different parts of the body. The arrangement of the fibres depends upon the functions of the tissue

into which they enter; thus, in *tendons*, which connect muscles and bones together, they are parallel; in *ligaments* which connect bones together, and which resist strain, the fibres often cross each other in every direction. The structure of the fibrous membranes, which surround certain organs, as the heart, is similar. In the fibro-cartilages, there is a mixture of bundles of fibres with cartilaginous cells.

There are two forms of fibrous tissue, the *white* and the *yellow*, or the unyielding and elastic. They may be distinguished by the action of acetic acid, which causes the white to swell up and become transparent, and brings into view certain oval corpuscles supposed to be nuclei of formative cells; whilst upon the yellow it produces no effect. The white usually occurs in bands, marked by longitudinal streaks: the *yellow*, in long single branched, curling filaments, from the 1-5000th to 1-10,000th of an inch in diameter, often anastomosing with each other. It is found especially in parts requiring elasticity, as in the middle coat of the arteries, the vocal cords, the ligamentum nuchæ, particularly of quadrupeds, and the ligamenta subflava; also in other parts which are usually considered cartilaginous, as the external ear. They differ also in *chemical composition;* the white fibrous tissue, as ligaments, tendons, &c., being composed of gelatine, or rather converted into it by long boiling; the yellow being scarcely affected by boiling, or by weak acids, and supposed by Scherer to consist of proteine and two atoms of water.

The simple fibrous tissue is but sparingly supplied with blood, and it is but slightly susceptible of change.

The *Areolar* or *Cellular tissue,* like the simple fibrous, is composed of minute fibres interwoven together so as to leave innumerable *areolæ* or little spaces, which communicate with each other. Part of its fibres are of the yellow or elastic sort, but the majority are of the white variety. The interstices are filled, during life, with a fluid resembling dilute serum of the blood. It is very elastic and extensible in all directions. It has not, properly speaking, *vital* properties, for its sensibility is dependent upon the nerves

which pass through it, and its contractility upon the muscular tissue of the vessels which traverse it.

The areolar tissue abounds in nearly all parts of the body; thus it binds together the different muscular fibres, forms septa between muscles, unites the elements of nerves, glands, &c., and binds together the fat-cells. It is not, at present, believed to penetrate the hard tissues, as the bones, cartilage, and teeth. Its design is to allow a certain degree of mobility of parts, and it serves as a bed for nerves and vessels.

The quantity of fluid in the areolar tissue varies; it is dependent, not upon any *secreting* power of the tissue, but merely upon the transudation of the watery portion of the blood circulating in the vessels. If there is a want of tone in the walls of these vessels, or an impoverished condition of the blood, there is an increased tendency to transudation, constituting one form of dropsy; the elasticity of the tissue is destroyed by the effused fluid, and the part *pits* on pressure. Sometimes the matter effused is of a semi-fibrous or gelatinous nature, producing great hardness and swelling. The free communication between all parts of the areolar tissue is seen in the influence of gravity upon dropsical effusions; and still more, by the whole body becoming distended from an emphysema of the lungs.

The Areolar issue is capable of speedy regeneration, as seen in cases of loss of substance. As to its precise *mode* of production, microscopists are not determined,—some thinking it due to the transformation of cells, others to a simple coagulation of fibrine, under peculiar circumstances.

The *Serous* and *Synovial membranes* are composed, essentially, of areolar tissue; their free surface being covered by an epithelial layer, which lies upon a basement-membrane. Below this is a condensed layer of areolar tissue, which gradually passes into a looser texture, constituting the *sub-serous* layer. The fibres composing these tissues belong to the yellow or elastic variety; hence they are yielding and elastic. Their fluid resembles the serum of the blood, and it is probably merely the effect of transudation from the vessels, and not a proper secretion. In the synovial

capsules and bursæ, there is a greater proportion of albumen. The serous membranes, like the other members of this class, possess but little sensibility in health. Whenever found in the body, they always form shut sacs or cavities; the only exception being in the case of the female peritoneum, which is open at two points where it communicates with the Fallopian tubes.

The *mucous membranes* and *skin* are also made up chiefly of areolar tissue. These two textures may be considered as continuations of each other, only modified in different parts, according to the functions to be performed. They are everywhere extremely vascular, but the vascularity of the skin is chiefly destined for the nervous system, and is necessary for general sensation, while that of the mucous membranes is subservient to secretion and absorption. The skin and mucous membranes are merged into each other at the various orifices and outlets of the body; thus we have the *gastro-intestinal*, the *bronchio-pulmonary*, the *genito-urinary*, and the *mammary* mucous membrane, and some other smaller divisions. Hence, the great distinction between serous and mucous membranes, is in regard to their *arrangement* as well as their *function*. For while the former are shut sacs, whose contents are not designed to undergo much change, the latter constitute walls of tubes and cavities, which have free communication with the outer surface, and in which, constant change is taking place. All the organic functions are performed by the epithelium-cells of mucous membranes.

The composition of mucous membranes and skin resembles that of the serous membranes; both consist of an epithelium or epidermis, a basement-membrane, and the proper areolar tissue, with its vessels, nerves, &c. The epithelium and epidermis consist of cells,—those of the epidermis being arranged in several layers, and designed merely to afford protection to the subjacent texture, while those of the epithelium are connected with the processes of secretion. The basement-membrane resembles that of serous membranes;—it is particularly evident in the tubuli uriniferi of the kidney. The areolar tissue of the skin is very distinct; it contains both sorts of fibres, and hence it yields *gelatine*

on boiling. The skin also seems to contain some non-striated muscular fibre. The skin is far more abundantly supplied with nerves than the mucous membranes; hence the sensibility of the former is very acute; that of the latter, very low.

Of the *sclerous*, or *hard tissues*, sufficient has already been said, so far as relates to the simple fibrous tissues, composed of the white or yellow fibres; there yet remains to be considered, under this head, the *cartilaginous*, the *fibro-cartilaginous*, the *osseous*, and the *corneous* tissues. In each of them, the constituent cells continue to form part of the structure, being sometimes imbedded in an intercellular substance, or matrix, and again consolidated together by a deposit of earthy matter, as in the case of bones and teeth.

Cartilage, in its simplest form, consists merely of nucleated cells, and strongly resembles the cellular structure of plants. In other forms, however, the cells are imbedded in an intercellular substance called *chondrine*, a species of gelatine. It requires longer boiling to dissolve it, and is not precipitated by tannic acid; though it is by acetate of lead, acetic acid, alum, and sulphate of iron, which do not affect gelatine proper.

All the fœtal cartilages are composed of chondrine; but as soon as ossification commences, it gives place to gelatine,—there being no chondrine in the bones. The *permanent* cartilages, however, still contain only chondrine; but if bony deposits take place in cartilages, it is then replaced by gelatine. Chondrine corresponds more with proteine in its composition than does gelatine; it is found exclusively in the true cellular cartilages; the fibro-cartilages, ligaments and tendons yield gelatine.

Cartilage likewise contains some mineral matters, as the sulphate and carbonate of soda, and carbonate and phosphate of lime. The latter increases in quantity as age advances, causing a disposition to *ossification*.

The cartilage-cells are multiplied by a sort of doubling or division, each separate portion forming for itself an envelope out of the intercellular substances. They are known by the name of *cartilage corpuscles*. Some cartilages retain throughout their primi-

tive cellular form,—as the articular cartilages, the cartilages of the nose, the eyelids, the trachea, the bronchi, and the larynx (except the epiglottis); also the cartilages of the ribs, and the ensiform cartilage.

Fibro-cartilages are formed, when the hyaline, or intercellular substance, assumes a fibrous character; and this may be elastic, or non-elastic. The fibrous character is seen in those cartilages which unite the bones by synchondrosis, as in the vertebræ and pelvis. The yellow fibrous cartilage is seen in the epiglottis, and concha of the ear.

Like the tissues already described, the cells of cartilage are nourished without coming into direct contact with the blood. No vessels penetrate the cellular cartilages in a state of health. They are, however, surrounded by vessels, which form *ampullæ* or varicose dilatations at their edges, or on their surfaces: from these the cells are nourished by imbibition, those which are nearest receiving the nutriment, and transmitting it to the more remote. In a state of inflammation, vessels are seen in the substance; but it is believed that these vessels exist in a new tissue developed by the inflammation, and not in the true cartilage. When undergoing ossification, vessels are seen in them; they do not, however, ramify extensively, but leave large islets unsupplied. The fibro-cartilages are more vascular, but in them the vessels do not penetrate the *cellular* portion.

Cartilage has comparatively little vitality or sensibility; it resists decomposition for a long time. It is doubtful whether a loss of substance is ever repaired by true cartilaginous tissue.

The *cornea* closely resembles cartilage, particularly the cellular form; but the cells are less numerous. According to Messrs. Todd and Bowman, it consists rather of a peculiar modification of white fibrous tissue, in which the fibres, which, in the sclerotic, have been densely interlaced, flatten out into a membranous form, and constitute a series of numerous laminæ, united to one another by delicate processes. There are two sets of vessels surrounding the margin of the cornea; the superficial belong rather to the conjunctival membrane; they project over the cornea about one-eighth

of a line, and then return as veins. The deep-seated layer does not pass into the true cornea; the vessels terminating in veins just where the sclerotic coat is joined by the cornea. In inflammation, both sets of vessels extend through the cornea; the superficial vessels sometimes form an elevated band around the margin. The *crystalline lens* also resembles cartilage in its structure. It is composed of fibres which are united into laminæ by a process of interlocking of their margins. The fibres are made up by a series of delicate cells, which coalesce at an early period. In the healthy state, it is not permeated by vessels, these being confined to its capsule. The lens is chiefly composed of albumen, or of a matter resembling globuline. The *vitreous humour* is made up of a cellular structure, which contains a transparent fluid consisting of water holding albumen and saline matter in solution. The cells have no very direct communication with each other. It is not permeated by blood-vessels, these being spent upon its envelope, and contributing, along with the plexus of the ciliary processes, to afford it nourishment.

The *Osseous tissue*, including the *Teeth*, is especially entitled to the name of *hard*, since in it, the cells which have been continued as a permanent part of the structure, have been filled up with a dense inorganic deposit, consisting of the phosphate and carbonate of lime. The general characters of the osseous tissue vary according to the shape of the bones. The long bones have their shaft composed of a compact structure, which is pierced by a central medullary canal. Their extremities are made up of cancellated structure, the cancelli freely communicating with each other, and with the cavity of the shaft; the whole being covered with a thin lamina of solid bone. In the thin flat bones, as the scapula, the two hard surfaces are connected together by cancellated structure. In the thicker flat bones, as those of the cranium, their cancellated structure is more evident, constituting the *diploe*. Again, in some very thin lamellæ, as the ethmoid and sphenoid bones, we find but a single layer of osseous matter.

Although a thin lamella of bone appears to be homogeneous, it is found, when viewed by the microscope, to consist of minute

granules cohering through the medium of gelatine. In the midst of these, numerous dark spots of a peculiar radiating appearance are observed, which are named *osseous* or *Purkinjean corpuscles.* These were formerly considered to consist of calcareous matter, but are now known to be only *lacunæ* or open spaces; and the rays proceeding from them are very minute tubes, called *canaliculi.* These passages are too small to admit the blood globules; but they may allow the fluid parts of the blood to pass, and thus conduce to the nutrition of the bony structure. The nutrition is effected, just as in cartilage, by imbibition through cells, which are placed between the lamellæ and the blood-vessels, which are minutely distributed over the delicate membrane lining the cancelli. This membrane is continuous with that which lines the cavity of the shaft.

The mode by which the *solid* parts of bones are nourished,—such as the shafts of long bones, and the external plates of the flat and thick bones, is by means of the *Haversian canals.* Their diameter varies from 1-2500th to 1-200th of an inch. They form a network in the interior of the hard structure, and transmit blood-vessels. In the long bones, these canals run in the direction of the shaft, and they communicate freely with each other, with the cancelli, and with the exterior surface. They are lined with a membrane which is continuous with that of the external surface, and also with that of the central cavity, and the cancelli; and between the osseous substance and the vascular membrane, there is a layer of cells, as in the case of the cancelli. Thus it appears that the whole bony texture is enclosed in a membrane, upon which radiate blood-vessels, that supply the nutritive materials, through the intervention of cells.

The *medulla*, or marrow does not seem concerned in the nutrition of bones. It is altogether absent in the bones of birds; the cavity in them being filled with air, which is admitted from the lungs, thus being subservient to aeration.

Bones are composed of *animal* and *calcareous* matter. The calcareous matter may be entirely removed by digestion in weak nitric or muriatic acid. The substance left is the animal matter,

which is cartilaginous in its appearance, and consists of gelatine. The calcareous matter may be isolated by the action of a heat sufficiently strong to destroy the animal matter. This leaves all the calcareous matter in a very friable state. The calcareous matter is composed of the phosphate and carbonate of lime,—chiefly the former. In callus, exostosis, &c., the proportion of the carbonate is much greater than in the healthy bone; but in *caries* it is less. The composition of the phosphate of lime in bones is three atoms of acid, united to eight atoms of base (Graham). Some chemists have thought there was a little fluoride of calcium in bones, also phosphate of magnesia, oxides of manganese and iron, and chloride of sodium, in very small quantities.

The relative proportion of animal and calcareous matter in bones, varies in different animals, also in the same animal according to the age; and even in different bones of the same skeleton. Young bones contain most animal matter; those of old persons most earthy matter, which renders them more brittle. This brittleness, also, at times, occurs as a congenital defect, rendering the subject of it very liable to fractures. The more solid bones contain a larger amount of calcareous matter than the more spongy ones; thus the temporal bone contains 63½ per cent., whilst the scapula has but 54 per cent.

The shells of Invertebrata grow in a very different manner from the bones of vertebrata. In the former, the growth takes place only by additional deposits upon the *surface;* in the latter, by an *interstitial* deposit. The corals, for instance, are not built up, as was formerly supposed, by little animals, as the bees construct their cells; but the calcareous matter (carbonate of lime), is deposited in the cells of the living tissue, as a *true secretion* of these cells, from the surrounding water. The amount of animal matter in this structure is extremely small, hence it is not liable to undergo change. A stem or branch of coral *grows* only by superficial deposit; so that it is only the surface of such structure that is, properly speaking, alive; the great mass being perfectly inert. In this way, the growth of coral may proceed to an indefinite extent.

The shells of the Mollusca are formed and grow in a similar manner. The univalve shells, as that of the snail, are always conoidal, the large end being open, through which the animal can protrude itself. In these, the new deposit occurs upon the open extremity, by which means the cavity is enlarged. In the bivalve shells, as the oyster, the deposit is made in a similar manner; each successive lamina being interior to the preceding, or next to the living surface of the animal; but it also projects beyond it, so as to enlarge the capacity of the shell; these laminæ are easily seen in the oyster. The proportion of calcareous and animal matter varies in different shells. In some, the organic matter can scarcely be detected, but in others it is so abundant as to assume the form of a thick membrane, when the calcareous matter has been removed by an acid. This membrane is evidently made up by an aggregation of cells, either hexagonal, or of a prismatic elongated shape, in which the carbonate of lime is deposited.

The same mode of growth is found in the Crustacea and other Articulata—as the lobster and crab. These animals *exuviate* or cast off their bony or hardened cases whenever their increased size demands it; and this process of moulting takes place, just like the desquamation and new formation of epidermis in man. The new shell is formed by the cells of the subjacent membrane. The casings of some of the Articulata, as the beetle, consist of layers of epidermic cells, filled with a horny matter. The dense shells of the Crustacea are composed of similar cells filled with a substance resembling dentine, covered exteriorly with pigment cells.

The bones of the Vertebrata *grow*, just like the soft parts, by interstitial absorption and deposit; and these processes continue even after the bone has attained the full size. This power of growth is not so much required from the waste occasioned by decomposition, as for the reparative process in case of any injury.

The conversion of cartilage into bone commences at minute points called *puncta ossificationis*. These are made by a development of canals, containing vessels at certain spots. There is usually one for the shaft of each long bone,—placed near its centre, and

one in each of its epiphyses. The flat bones have one about their centre, and one in each of their larger processes.

The parts of a bone having distinct centres of ossification do not connect together till a late period; sometimes they always remain distinct. This is remarkably the case in some of the lower animals,—as seen in their vertebræ, and in the bones of the cranium.

Before any ossific deposit occurs, the cartilaginous cells begin to arrange themselves in long rows corresponding with the axis of the bone. These rows are still separated by means of the intercellular substance. The first bony matter is deposited in the intercellular substance, by which deep cups of bone are formed, holding the cartilaginous cells. This may be called the *first* stage of the process. The next stage consists in a transformation of the cells into bone. These at first become flattened against the bony shelves, and then absorb into their cavity the calcareous matter. They also coalesce together so completely as to remove the appearance of cellular structure. The nuclei of the cells, however, remain enclosed in the solid matter, thus forming cavities or *lacunæ*, which are the *Purkinjean bodies*. The *canals of Havers* are formed from the bony canals containing the cartilaginous cells.

Thus, one layer after another is converted into bone, until the whole becomes ossified. During this process, there is a *blastema* deposited in the cancelli and canals: from this the vascular lining of these canals appears to be formed. This lining is the source of the future growth and reparation of the bones. From this blastema also originate the fat-cells, which secrete the marrow.

The progressive growth of bone is accomplished both by superficial and interstitial deposit of osseous matter. Long bones increase in length chiefly by addition to their extremities, as is proved by inserting shot in the shaft of a growing bone,—the distance between the shot remaining the same after the bone has attained its full size. The increase in thickness also takes place chiefly by external osseous deposit,—which is the cause of the *lamellated* appearance of bones.

The *interstitial* change is chiefly seen in the formation of the

medullary canal. Originally, in very young animals, this cavity does not exist, its place being occupied by small cancelli; these gradually enlarge until they coalesce with one another, so as to form a continuous tube. During this process, the shaft of the bone surrounding the medullary canal, also increases in thickness by interstitial growth; successive layers of cells being formed within those that preceded them, by which the latter are pushed outwards, and then the cancelli become increased in size beyond the limits marked out in the intercellular substance. This mode of arrangement for the shaft of the bone is proved, on mechanical principles, to be the strongest that could be devised.

The difference in the rapidity of the growth and nutrition of bones is well seen by feeding an animal on madder, which has a peculiar affinity for phosphate of lime. The rapidity of the colouring of the bone is inversely to the age of the animal.

The process of regeneration of bone is very complete. Both the external and internal periosteum are concerned in it, though, properly speaking, the real production of new tissue is due to the bony spiculæ adhering to the periosteum. Thus, it is found in comminuted fractures, that each fragment of bone, in connexion with the vascular membrane, becomes the centre of new osseous formation; and that the reparative process is rapid in proportion to the number of these centres.

When a bone is fractured, organizable lymph is thrown out, not only from the vessels of the bone, but from all the neighbouring parts. This becomes vascular, and is converted succesively into cartilage and bone, and is termed *callus.* When the extremities of a fractured bone are brought together, it is found that ossification of the new matter commences at the centre, where the ends of the medullary cavities come together, forming a sort of plug, which enters each end. This is termed, by Dupuytren, the *provisional callus*, and is generally formed in five or six weeks after the fracture. The formation of the permanent callus, which unites the bony edges together, occupies several months, during which the provisional callus is gradually absorbed, so as to restore

the continuity of the medullary canal. The permanent callus has all the characteristics of true bone.

Necrosis, or death of the bone, results from extensive injury to either of the membranes. When this occurs, the reparative process commences on the part which is sound,—the external membrane throwing out new matter on its *interior*, or the internal membrane doing the same on its *exterior*. If the whole bone is necrosed, reparation can only occur from the living bone at the two extremities, and must, consequently, be extremely slow.

The Teeth.—The Teeth, though resembling bone in their structure, have a different origin; commencing in papillæ of the mucous membrane of the jaw. The substance of these papillæ is composed of spherical cells imbedded in a gelatinous substance, resembling that of a forming cartilage. The surface of these papillæ is composed of a dense membrane. A small arterial branch is distributed to each papilla, and spreads out into a tuft at its base. The papilla enlarges by the formation of new cells, the materials for their growth being supplied by the blood-vessels; and when it has reached its full size, the process of solidification commences, by the deposit of dentine in the cells.

The teeth of man, and the higher animals, consist of three very different elements, the dentine or ivory, the enamel, and the cementum. The *Dentine* or *Ivory* contains more calcareous matter than exists in bones; it amounts to 72 parts in 100. Of this, $64\frac{1}{2}$ parts consist of phosphate of lime; $5\frac{1}{2}$ parts of carbonate of lime; and the remainder of phosphate of soda and magnesia, with chloride of sodium. When viewed by the microscope, dentine is found to be traversed with minute tubuli, which appear like dark lines close together, running in a wavy direction from the cavity of the tooth towards its surface. They sometimes give off lateral branches. The diameter of even the largest of these tubuli is very much smaller than that of the blood-corpuscles; hence they probably absorb nutriment, like the canaliculi of bone, from the vascular surface.

The central portion of the tooth is hollow, and is occupied with the remains of the *pulp*. This cavity is lined by a vascular mem-

brane, and is continued through each fang, or root. From these cavities the dental tubes radiate towards the circumference. This central canal is very analogous to the Haversian canal of the bones. In some of the lower animals, instead of a cavity, we find a network of canals extending throughout, and communicating with the Haversian canals of the jaw.

The mode of conversion of the cells of the dental papilla into dentine, very much resembles the formation of bone. The cells arrange themselves in lines or rows, extending from the inner part to the circumference. These gradually secrete the calcareous matter, at the same time approximating together. The minute tubuli are due to the nuclei of the cells not being filled up, just as in the case of the canaliculi of the bones. Although the coalescence of the cells in the teeth of man is very complete, still, traces of them may be seen by the microscope. The dentine of man and of mammalia is not permeated by blood-vessels; but in some of the lower animals there are canals—prolongations of the central cavity, which transmit vessels, as is seen in bones. The central pulp sometimes becomes ossified,—usually the result of age. The *nutrition* of dentine is accomplished like that of bone. It is most rapid in the young, as seen by feeding animals on madder; a prolonged use of it being requisite to affect adults.

Where the teeth consist only of dentine, the process of consolidation of the papillæ is very simple. Sometimes a tooth thus formed remains merely attached to the mucous membrane of the jaw, as in the shark, and is liable to be torn off; but they are easily reproduced, as the development of the papillæ appears to be unlimited.

The *enamel* is the hard covering upon the exposed portion of the teeth. It is composed of long prismatic cells of a hexagonal shape, arranged close together, and presenting their ends to the surface of the tooth. Their diameter is about the 1-5600th of an inch. The course of the prismatic cells is wavy, and is marked by striæ. There is no appearance of tubuli or vessels. Enamel contains only two parts of animal matter, in a hundred; of the remainder, there are $88\frac{1}{2}$ parts phosphate of lime, 8 of carbonate

of lime, and $1\frac{1}{2}$ of phosphate of magnesia. It is by far the hardest and most dense of organized tissues, and resembles mineral substances. In man and the carnivora, it covers the crown of the tooth only; but in most of the herbivoræ it forms a series of alternate plates with the cementum, which dip down into the dentine, presenting the edges at the triturating surfaces of the tooth, so as to form an uneven surface. The enamel is more frequently absent than the other dental tissues.

The *cementum* or *crusta petrosa* covers the root or fang of the tooth. It has all the characters of true bone. It is liable to hypertrophy, from inflammation, and in this way exostoses may form upon the root, rendering it difficult to extract. In the very young tooth, the cementum covers the crown also, but being very thin, it soon wears off, leaving the enamel exposed. The primitive papilla of the tooth is originally enclosed within a capsule. Between the capsule and the papilla a sort of epithelium is developed, which becomes the enamel by subsequent calcification. The cementum is formed by the capsule itself becoming converted into bone.

The dental papillæ first appear about the seventh week of embryonic life, in the form of little prominences upon the mucous membrane of "the primitive dental groove," which runs along the edge of the jaw. About the tenth week the edges of this groove begin to send out processes which approach each other, so as to form a series of follicles. These follicles are completed by the thirteenth week, when the papillæ have attained such a size as to protrude from the mouth of the follicles. By the fourteenth week the two edges of the dental groove have met over the follicles, so as to enclose each papilla in a distinct capsule. Soon after the closure of the follicles, the formation of dentine commences by the solidification of the cells of the original papilla. Before this takes place, however, provision is made for the production of the second or permanent teeth, whose capsules are only buds or offsets from the upper part of the capsules of the deciduous teeth. At first these capsules are open follicles communicating with the others, but they are gradually closed in, and

finally, entirely detached from them. Whilst the dental papilla is undergoing conversion into dentine, its follicle increases in size, so that a space is formed between its inner surface and the papilla; this space is occupied by a gelatinous matter called the *enamel-pulp;* but it is only a thin layer of this which is converted into enamel, the remainder being removed.

Thus we have three stages in the development of the human tooth—the *papillary,* the *follicular,* and the *saccular.* Besides these, there is also the *eruptive* stage, which consists in the tooth bursting through its capsule by its growth from the root; by the same process it also penetrates the gum. The pressure of the tooth upon the nerves of the gum is often the source of great disturbance of the health during dentition; the best remedy is free scarification of the gum.

The deciduous, or milk-teeth number *ten* for each jaw; the second or permanent teeth amount to *sixteen* in each jaw. The first permanent molar is formed precisely like the milk-teeth, but it is not completed till a later period; it is in fact a true milk-tooth, so far as its formation is concerned. The second permanent molars are formed as offsets, or buds from the first; and at a still later period, the capsules of the third permanent molars, or *dentes sapientiæ* are formed as offsets from those of the second. The last are not usually developed until maturity.

The following is the average time at which the temporary and permanent teeth make their appearance:—

TEMPORARY, OR DECIDUOUS TEETH.

	Months.
Central Incisors,	7
Lateral Incisors,	8—10
Anterior Molars,	12—13
Canines,	14—20
Posterior Molars,	18—31

PERMANENT TEETH.

	Years.
First Molar,	6½ to 7
Central Incisors,	7—8

	Years.
Lateral Incisors, - - - -	8—9
First Bicuspid, - - - -	9—10
Second Bicuspid, - - - -	10—11
Canines, - - - -	12—12½
Second Molars, - - - -	12½—14
Third Molars, - - - -	16—30

The teeth are to be considered rather as a part of the external or dermo-skeleton, than of the internal or osseous-skeleton.

The *Hair* is produced much in the same manner as the teeth,—from a pulp enclosed in a follicle. The hair-follicle is formed by an inversion of the skin, just as the tooth-follicle is made by an inversion of mucous membrane; and it is lined by a continuation of the epidermis. At the bottom of the follicle there is a papilla composed of cells; the exterior of this is called the *bulb*, and the interior, being soft, is named the *pulp*. The follicle is very vascular.

It was formerly supposed that the hair was a mere horny secretion from the pulp. The microscope shows it to consist of two distinct portions, a *cortical* part, of a horny, fibrous nature, and a *medullary* or internal portion. These distinctions are best seen in the bristles of the hedgehog, and the quills of the porcupine, which are only enlarged hairs. The cortical portion gives firmness to the hair. The medullary substance consists of an aggregation of large cells, the contents of which are not fluid. In the human hair, the greater part is made up of the horny cortical portion, which is fibrous.

The hairs are invested with very minute scales, like those of the epidermis, arranged in rows overlapping one another, which gives the appearance of delicate lines on the surface. The colouring matter of the hair seems to be owing, in part at least, to iron, and it resembles hæmatin. It is more abundant in dark than in light hair. The fibres of the cortical substance of the hairs are believed to be made up of cells altered so as to assume the elongated form, and which have secreted the horny matter into their interior. The medullary matter is probably developed from the cells of the pulp. Thus the hairs grow from the base, just as the

teeth of some animals grow from persistent pulps. When thus formed, the hair is not very liable to undergo change, but occasionally it is affected with changes at its base;—thus violent mental emotion has been known to turn it gray in a single night; this must have been owing to the secretion of a fluid at the base, capable of affecting the colour, transmitted through the medullary portion. A similar power of imbibition is seen in the disease termed *Plica Polonica*,—where drops of blood also have been said to exude from the cut extremities of the hairs.

SECTION II.

TISSUES COMPOSED OF A PROTEINE, OR OXY-PROTEINE ELEMENT—THEIR FUNCTIONS ORGANICO-CHEMICAL.

The only tissues comprised under this division are the *epithelial*, which are here treated of as distinct tissues, on account of the very important offices which they perform in the animal economy.

Their anatomical structure consists of a basement, or primary membrane, from the nuclei, or "germinal spots" of which there is a development of successive generations of desquamating or moulting cells. When these cells have attained their full development, and have reached the free surface of the membrane, they burst open and throw out their contents;—this essentially constitutes *secretion*.

The *Epithelium* is the delicate covering, composed of a layer of cells, which lines the interior of all the mucous membranes of the body, even into their prolongations of crypts or follicles, and glands; it also exists upon the serous and synovial membranes. Its function is partly protective, like that of the epidermis; but it generally performs a much higher part in the action of the system, since all the secretions of the body are the result of the action of epithelium cells. Of all the organic cells these are probably the most rapidly reproduced; successive generations of them are con-

stantly being developed from the permanent nuclei of the subjacent basement-membrane; as they push towards the surface they fill up with the particular fluid which they have elaborated from the blood, and finally, having attained their full growth, they burst open, throwing off their contents, either upon the free surface of their membrane, as in the case of the secretion of mucus, or else within follicles or tubules, as in the case of glands. It has been supposed by some observers that a complete cast of the mucous membrane of the alimentary canal is in this manner thrown off every twenty-four hours. The cells thus desquamated are always replaced by others.

The epithelium is presented under two forms,—the *tessellated* or *pavement*, and the *cylindrical*. The former is composed of flattened polygonal cells, lying in apposition with each other, forming a kind of pavement. It is found in serous and synovial membranes, and in the lining of the heart and blood-vessels; also, in some of the mucous membranes, as that of the mouth and the smaller bronchial tubes, and the ultimate tubuli of glands. The epithelium of serous membranes is endowed with less activity than that of mucous membranes; it does not appear to be concerned in the elaboration of any peculiar secretion, with the exception, probably, of the synovia.

The *cylinder epithelium* is composed of cylindrical cells, arranged side by side, with one extremity resting upon the basement-membrane, and the other extremity free. The perfect cylindrical form of these cells is only seen when the surface upon which they rest is flat. If it be convex, they have a conical shape, the apex being towards the basement-membrane; if concave, the apex is towards the free surface. The cylinder epithelium is found in the alimentary canal, from the cardiac orifice of the stomach downwards; in the larger ducts of the glands which open into it, giving place in the ultimate follicles to the tessellated variety. It is well seen in the villi of the intestines.

Both forms often pass into one another, and are frequently fringed with delicate hair-like processes termed *cilia*, which vary much in length,—from the 1-500th to the 1-13,000th of an inch.

They are usually flattened and tapering, and present an almost constant wavy motion. In the lower aquatic animals their function seems to be to renew the water in contact with their surface, for the purpose of aeration, and also to serve as organs of prehension and locomotion. The *cause* of ciliary motion is not known. It does not depend upon either nervous or muscular energy, since it is unaffected by either electricity or narcotics. It seems independent of the will, and even of the life of the animal, since it has been seen in isolated epithelium cells many days after death; but the length of time is much less in warm-blooded animals. The sole conditions for the ciliary movement appear to be the integrity of the attached epithelium cell, and the presence of a fluid.

In man, cilia have been observed in the nasal cavities, frontal sinuses, maxillary antra, lachrymal sacs and ducts, posterior surface of the velum pendulum, the Eustachian tube, the larynx, trachea and bronchi, the uterus, upper part of the vagina, and the Fallopian tubes. In all these positions, with the exception of the minute bronchi, the cilia are attached to the cylinder-epithelium; and their function evidently is to propel the secretions to the external orifices, as their direction is *outwards*. They have been discovered also in the brain; but here their function is unknown. In certain of the lower animals they have been found in the blood-vessels, their function here being doubtless to aid in carrying on the circulation.

The above description presents a general view of the character and offices of the epithelial tissues. While they agree in all essential points, they present, at the same time, certain distinctive marks by which they may be arranged under separate divisions, as the *alimentary*, the *respiratory*, the *glandular*, the *epidermoid*, and the *genito-urinary*. Of the alimentary epithelium, a portion—that lining the mouth and fauces—is both protective and secretory; that lining the follicles of the stomach is destined for a specific office, namely, the secretion of the gastric juice; that which exists in the intestines is also secretory. The glandular epithelium varies exceedingly, from a simple depression, or follicle, to the most complex and tortuous structure; although in all the same general plan

is carried out,—the purpose aimed at being to provide as large an extent of secreting surface as possible in the smallest possible space, wherever a highly elaborated secretion is to be provided for, Hence, the convoluted character of the testis and kidney.

The rapidity of the destruction and renewal of the epithelium-cells varies with the function of the part. Wherever the secreting operations are most active, and the cell-life consequently shortest, the tessellated form is the one generally met with,—as in the ultimate glandular follicles, and smaller bronchial tubes. The remains of the cells are, in every case, thrown off along with their contents.

Another point of distinction is found in the *contents* of these cells. Although they appear to be formed alike, and to pass through the different phases of their brief existence in a similar manner, yet the results are widely different; the liver-cell alone secretes bile; the kidney-cell exclusively separates urea and uric acid; the cell of the mammary gland alone secretes milk; and so of all the rest. All these products, moreover, are derived from one common reservoir—the blood; the *selective power* residing within the cell. Hence, we see that Secretion is only a process of *cell-growth*, the various cells taking up from the blood the materials necessary for their nutrition, then bursting or wasting away, and discharging their contents into channels which communicate with the exterior of the body. In many cases, all that the cells effect is the mere separation from the blood, of substances pre-existing there, as the fat, &c.; in other instances, they exhibit a power of transforming, decomposing, or combining the pre-existing elements. It is not certain that they ever really *create* a new product, although the secretion of milk, and of the spermatic fluid, are believed by some to be instances of a true creative power in the cells. This is the highest power which cells possess; it is termed the *metabolic force*, by Schwann.

The simplest function of the epithelium-cells of mucous membrane is the secretion of *mucus*, which is intended to protect them from the contact of the air, and other sources of irritation. Mucus is a transparent tenacious substance, insoluble in water, but dis-

solved in weak alkaline solutions, from which it is precipitated by acids. A substance resembling mucus may be produced from any fibrinous exudation, or even from pus, by treating it with a small quantity of liquor potassæ. Mucus also contains certain bodies, termed *mucus corpuscles*, together with some salts, and epithelium-scales. In some parts, a sufficient supply of mucus is afforded by the cells upon the surface of the membrane; but in other situations, as in the alimentary canal, the demand is much greater; hence the use of the numerous follicles and crypts to extend the surface. The cells which lie upon the surface of mucous membranes have their origin in the germs of the basement-membrane. Those which are found in follicles seem to occupy rather the cavity than the walls, and to be reproduced from a *germinal spot* in the blind extremity of the follicle. The same is true of the ultimate follicles of glands.

The *Epidermic cells* are closely allied to the epithelium-cells in structure, and to a certain extent also in function; the epidermis being designed merely to protect the surface of the true skin, while the epithelium, as we have seen, conjoins to this a higher function. They are continuous with each other at the various outlets of the body, as has already been noticed when treating of the mucous membranes.

The epidermis or cuticle was formerly thought to be an inorganic exudation from the skin, and to be homogeneous in texture. It is now known to consist of several layers of cells, the outer ones of which are continually being thrown off, giving place to those beneath; the successive crops being supplied by the basement-membrane. This desquamation is sometimes particularly rapid, as after scarlatina. It covers the whole surface of the body, not excepting the cornea, as may be seen in the desquamation of the skin of snakes.

In the gradual progress of the cells from the inner to the outer surface of the epithelium, they become changed in form. The innermost layer consists of nuclei in various degrees of development into cells, soft and granular. This was formerly considered a distinct tissue, and named *rete mucosum*, being supposed to be

the seat of the colour of the skin. Passing from this layer outwards, we find the cells assuming a spherical form, then becoming polygonal, and gradually flattened, until at the surface they are merely dry scales. The flattening results from the drying of the contents from exposure to the air. The number of these layers varies in different parts of the skin—being greatest in those places which are subjected to pressure, as the palms of the hands and soles of the feet. The epidermis is continuous with the epithelial lining of the ducts of the sudoriparous and sebaceous glands.

The composition of the epidermis is similar to that of hair, horns, nails, and wool. Its sole object seems to be to protect the skin. When abraded, it is rapidly regenerated.

The *Nails* are only an altered form of epidermis, being the product of cells, which gradually dry into scales; and these remain adherent. A new growth is constantly occurring at the groove of the skin in which the nail is fixed, and also, probably, from the whole subjacent surface.

The *pigment cells* are found intermingled with the epidermic cells. They secrete the colouring matter. They are not very evident in the white, but are well marked in the dark races. Their growth and development are like those of the epidermic cells. They are particularly evident on the inner surface of the choroid coat of the eye, constituting the *pigmentum nigrum.* Their form is polygonal. Their dark colour is thought to be owing to a great number of granules existing in the cells. They contain a large amount of carbon. The growth of these cells is dependent somewhat upon the influence of *light,* as seen in freckles, tan, and the swarthy hue of persons long exposed in tropical climates. Some have even attributed the dark skin of the negro to this cause operating through many successive generations. An occasional development of them occurs during pregnancy, particularly in the areola of the nipple. On the other hand, a deficiency of them sometimes exists, either partial or entire; this occurs both in the white and black, and such persons are called Albinoes.

SECTION III.

TISSUES COMPOSED OF FIBRINE AND NEURINE—MUSCULAR AND NERVOUS TISSUES.

THE muscular and nervous tissues afford a good illustration of the *compound tubular tissues*, which are composed of tubes resulting from the coalescence of cells, and filled up with a secondary deposit.

I. MUSCULAR TISSUE.—A muscle, when examined by the naked eye, is found to consist of fasciculi, or bundles of fibres, arranged together with great regularity in the direction in which the muscle is to act. These bundles are connected together by means of areolar tissue. The fibres of the fasciculi are seen by the microscope to be each made up of a number of minute fibrils bound together by delicate areolar tissue; these last are the ultimate muscular fibres, or *fibrillæ*.

Ultimate muscular fibre is presented under two forms,—the *striated*, and the *non-striated*. The striated form is found in the voluntary muscles, or the muscles of animal life; the non-striated, in the muscles of organic life. The striated muscular fibre presents the appearance, either of very delicate *fibrillæ*, by its splitting up in the longitudinal direction, or of a series of *disks*, by its separating in a transverse direction. The real composition of the fibre appears to be of flattened disk-like cells of uniform size. These are adherent both by their flat surfaces, and by their edges. The former adhesion being usually the most powerful, causes the fibre, when broken up, to present the appearance of fibrillæ, each of which is composed of a single *row* of the primitive particles. But when the lateral adhesion is the stronger, the cleavage is crosswise —in the form of disks, each of which is composed of a *layer* of primitive particles.

The muscular fibre is covered by a very delicate tubular sheath, called the *myolemma* or *sarcolemma*. This cannot always be distinguished on account of its transparency, but it is made evident by drawing the ends of a fibre apart, when its contents will some-

times separate without a rupture of the sheath. It may also at times be seen rising in wrinkles, on the surface of the fibre, when the latter is in a state of contraction. It may also be made evident by subjecting muscular fibre to the action of acids or alkalies, which make the contents swell up, so as to burst open the myolemma in spots, and cause a sort of hernial protrusion of the contents. This membrane is not perforated either by nerves or blood-vessels; in fact, it forms a barrier between its contents and the surrounding parts.

Muscular fibres, though commonly described as cylindrical, are really polygonal, resulting from pressure; the angles are sometimes rounded off so as to afford space for the passage of vessels. The size of the fibres varies considerably, not merely in different animals, but in different sexes, and even in different muscles of the same animal. In the human male, the average size, according to Bowman, is 1-352d of an inch; in the female 1-454th of an inch. The average size in reptiles and fishes is greater than in mammalia, but the extremes are much wider.

When the ultimate *fibrillæ* of the fibres are examined by a very high power, they are observed to present a beaded form, and to be made up of a linear aggregation of distinct cells, presenting an alternation of light and dark spaces. There is also a light border around the dark spaces, as well as between them. This transparent border appears to be the cell-wall; the dark space within this is the cavity of the cell filled with a refracting substance. When the fibril is relaxed, the cells assume an oblong shape, the greatest diameter being in the longitudinal direction; when the fibril is contracted, the transverse diameter of each cell is increased, so that the dark spaces become square, or their transverse diameter may even exceed their longitudinal one. Thus, it seems that muscular contraction consists essentially in an alteration in the form of the ultimate cells, arising from an attraction between their opposite walls. This closely resembles the contraction of vegetable tissues, whose component cells, when irritated, undergo a change of form, causing movement. The essential difference

between the two is, that muscular tissue is under *nervous* influence.

The diameter of the ultimate fibrillæ is tolerably uniform in different animals—being about 1-10,000th of an inch. It has been computed that the human muscular fibre contains from five to eight hundred fibrillæ; it varies, however, according as it is contracted, or enlarged. The average distance of the *striæ* is about 1-10,000th of an inch; but it is also subject to variations.

The muscular fibre of organic life (the involuntary muscles) is the non-striated. It consists of a number of filaments, which are tubular, like the preceding; their contents being granular, but without any definite arrangement into fibrils or disks, as in the former. The size is usually much less than that of the striated fibre. It is difficult to estimate their dimensions, owing to the variations in the degree of flattening which they undergo; from 1-2500th to 1-5600th of an inch is about their average diameter. They have a knotty appearance, which is due to the remaining nuclei of the formative cells. These muscular fibres, like the others, are collected into fasciculi or bundles, but these fasciculi are generally interwoven into a network without having any fixed point of attachment. This is the kind of muscular structure which is found in the stomach, intestinal canal, œsophagus, bladder, the pregnant uterus, also in the trachea and bronchial tubes, but not in the pharyngeal muscles. The heart contains a mixture of the striated and non-striated fibres. The middle coat of the arteries contains a modification of the non-striated variety. The latter is also found in the skin, occasioning by its contraction the appearance called *cutis anserina;* also in the dartos, causing the wrinkling of the scrotum.

In the development of muscular fibre, the sarcolemma, or tubular sheath, is first formed from cells uniting in a row, the intervening walls being broken down. The nuclei of the original cells sometimes remain, and may be seen projecting from the sides of the fibre. These projections are not so perceptible in the muscles of animal life, unless the fibre be treated with dilute acid, which brings them into view by rendering the nuclei more opaque. It

is highly probable that these nuclei continue to furnish the cells that compose the fibrillæ. Thus, it is found that the diameter of the muscular fibre of the fœtus is only one-third that of the adult; but as the size of the *ultimate particles* is the same in both, the growth can only take place by an increase in their *number*. Besides, every exertion of muscular power is attended with a decay of its particles, which must be made up by a regeneration of new structure; and this is probably accomplished by these nuclei out of the blood which circulates in the muscle. Hence, we see there is no difference in the early development of the striated and non-striated muscular fibre; but while the former continues on till fibrillæ are produced, the latter stops short of this.

The *vascularity* of muscles is very great. Though the ultimate muscular structure is not in actual contact with the blood, the capillaries are abundantly distributed through the spaces between the fibres; in this way their nutrition is accomplished. In proportion to the energy of muscular action, must be the amount of its nutrition, and of the supply of arterial blood. But it is well known, from the increased quantity of solid excretions that occur in the urine during muscular exertion, that there must be a correspondent degree of waste or disintegration of the muscular tissue. The products of this waste consist of the elements of muscular fibre in union with oxygen; these are carried off by the venous blood; and the loss is supplied, or the nutrition is kept up, by the fibrine of the arterial blood. Notwithstanding the rapidity of the interstitial changes accompanying its growth, it is very doubtful whether it is ever regenerated after an actual loss of substance. Wounds quickly heal through the intervention of areolar tissue, which gradually becomes consolidated, but never contractile.

Nerves are more abundantly distributed to muscles of animal life, than to any other tissue, except the skin. They do not penetrate the sarcolemma, but lie on the outside, like the capillaries. They do not, properly speaking, *terminate* in the muscle, since their ultimate fibres form loops, which either return to their original trunk, or else form a connexion with another. The muscles of organic life (non-striated) are sparingly supplied with nerves:

and these are chiefly derived from the sympathetic. Muscles are far less sensitive to external impression than other parts of the body. This is seen in amputations, where the greatest pain is occasioned in cutting through the skin, the muscles suffering comparatively little.

Every striated muscular fibre is attached by its extremities to fibrous tissue, the sum total of which, in any muscle, constitutes its *tendon*. The muscular fibre terminates abruptly by a perfect disk, the tendinous fibre being attached to the whole surface of this disk, and becoming continuous with the myolemma. Sometimes the muscular fibres are inserted obliquely into a tendinous band, as in the case of the penniform muscles. The various forms of muscles have reference solely to the mechanical purposes they are to accomplish: the *elements* of all are alike.

The chemical composition of muscle seems to be nearly identical with the fibrine of the blood. It cannot be perfectly analyzed, owing to the impossibility of separating the areolar tissue, vessels, nerves, &c., from it. The solid matter forms about 23 parts in 100; the remainder being water. Of the solid matter, about 7½ per cent. consists of fixed salts.

The characteristic of muscular tissue is the power of *contractility* under a stimulus. This is also seen in certain vegetables, as the sensitive plant, &c., and results, in them, from the contraction of their cells. The simplest form of muscular contractility—that of the muscles of organic life—closely resembles that seen in plants; thus the non-striated fibre contracts most readily by a stimulus applied directly to itself. The striated fibre, on the contrary, is more readily affected by a stimulus acting through the nerves supplying it. Muscular contractility is often spoken of under the heads of *irritability*, or the property of alternate contraction and relaxation, and *tonicity*, or a moderate and permanent contraction. Haller's doctrine that contractility is an *inherent* property of muscular tissue is believed to be correct. It is proved not to depend on the nerves, from the fact that a muscle, or even a single fibre, may be made to contract under a stimulus, when the nerves supplying it have been divided. Besides, the non-striated

fibre can scarcely be made to contract through the nerves, while a direct stimulus will cause immediate action.

Muscular contraction is excited most powerfully by electricity; but heat, cold, chemical agents, or even mere contact, will also act as stimuli. The effect of the stimulus will depend upon the kind of muscle acted upon; thus, in a voluntary muscle, only the fasciculus of fibres irritated will contract, the rest of the muscle being unaffected, and relaxation will soon follow. But if a portion of non-striated fibre be irritated, as in the alimentary canal, the contraction will be less sudden, but will propagate itself to other portions successively, and the relaxation will be less speedy; this is termed *peristaltic movement.*

The reason why division of the nerves, or paralysis, will be followed by a loss of muscular contractility, is because the nutrition of the muscle is impaired by its want of use; the muscles of animal life being called into action usually through the medium of the nerves. For the same reason, we see the wasting away of muscles which are not used. Dr. Reid's experiment proves this: he divided the sciatic nerve on both sides of a frog, and applied a moderate stimulus by means of galvanism to the limb of *one* side for two months, leaving the other limb untouched; at the end of that time, the muscles of the former were found unaltered in their nutrition and power of contracting, while those of the latter had wasted away and lost some of their contractility. This also explains the fact that in cerebral palsy, the irritability of the muscles remains unaffected, because they may still be called into action through the reflex system of spinal nerves.

If a nerve supplying a voluntary muscle be irritated, every portion of it is simultaneously affected. The ordinary actions of the voluntary muscles are executed through the channel of the nerves; and these nerves are derived either from the brain or spinal marrow. The ordinary actions of the non-striated muscles are caused by *direct* stimuli; indeed it is very difficult to excite contractions in them through the medium of the nerves. The sympathetic nerve chiefly supplies the non-striated muscles; but it is believed that the *motor* power in these is derived from the branches of the

cerebro-spinal system which are united with the true sympathetic.

When a muscle contracts, its *bulk* is not affected. It is shortened in the direction of its fibres, but its diameter is proportionally enlarged. It was formerly supposed that the ultimate fibres threw themselves into zigzag folds in contracting, but this has been disproved; each fibre shortens in a straight line. The striæ of the fibre approach each other more closely, in consequence of the approximation of the light and dark spaces of the individual fibrillæ. Bowman says that the contraction usually commences at the extremities of a fibre. The first appearance of it is a dark spot caused by the approximation of the striæ, and this forces out the fluid that was previously among the interstices of the fibrillæ, so as to cause the appearance of little vesicles beneath the myolemma, which is drawn up in wrinkles. The contractile power of a muscle is greatest when it is stretched to its full length, and not, as was supposed, when it is partially contracted. This was proved by Schwann, by attaching a delicate balance to the sartorius of the frog; the power of sustaining a weight, progressively diminished as the muscle shortened. Hence the inference that the *power* which causes muscular contractility must differ from galvanism, or any other force of attraction known to us, since all these forces increase in energy, as the attracted parts approach each other inversely as the square of the distance; but muscular force, as shown above, appears to act in the *direct ratio of the distance.*

When the ear is applied over a muscle in a state of vigorous contraction, a peculiar faint and rapid sound is heard, caused by the constant movement in its substance. This arises from the fact that the whole of the fibres are not in a state of contraction at once, but while some are passing from a relaxed to a contracted state, others are doing the reverse. Hence, although it is true, that in individual fibres contraction is speedily followed by relaxation, still the contraction of the *whole muscle* may be much prolonged. The occasional zigzag appearance of the fibres may be accounted for by the approximation of their extremities, in conse-

quence of the contraction of some neighbouring fibres, while their own condition is that of relaxation. In the heart, the whole of the fibres contract together, and relax simultaneously.

The essential condition for the manifestation of muscular contractility, is the abundant supply of oxygenated blood. The length of time during which the contractility remains after the circulation has ceased, is inversely to the activity of the respiration of the animal (Hall); thus in cold-blooded animals, it lasts much longer than in the warm-blooded. In man, the contractility of the several muscular tissues is lost in the following order after death,—the left ventricle first; the intestinal canal in about 50 minutes; the œsophagus in an hour and a half; the iris rather later, and last the auricles, especially the right. The following experiments prove the necessity of oxygen in the circulating blood: If the brain and spinal cord be removed, provided artificial respiration be kept up, the muscles will preserve their irritability; if the general circulation continue, and that of a particular muscle be cut off, that muscle will lose its irritability; if an animal be made to breathe carbonic acid, the muscles lose their irritability as soon as death takes place. In fact, the loss of the power in the heart to contract, from the presence of venous blood, is one of the immediate causes of death. If an animal be made to breathe oxygen, the contractility of the muscles is retained for a longer time than usual.

During muscular action the temperature slightly rises,—from one to two degrees. This may depend both upon the chemical changes which are then taking place, and upon the friction between the particles.

Some of the muscles are in constant action, as the heart, and the muscles of respiration; here the reparative process must be as constant as the waste; such muscles never experience *fatigue*. It is different with the voluntary muscles; the fatigue occasioned by a prolonged action is an evidence of their impaired condition, and rest is required to allow the process of nutrition to go on. The effect of continual moderate exercise of a muscle, is to increase its

size by increasing its nutrition: this occurs both to the voluntary and involuntary muscles.

The *tonicity* of a muscle is that constant tendency to contraction which is seen in every living muscle. It is shown by the retraction which occurs in the ends of a muscle when divided. In health, the tonicity of the different muscles is about balanced, but in paralysis of the extensors there is permanent flexure of the joints, arising from the tonicity of the flexors; this is seen in lead-palsy. The tonicity is proportionally greater in the non-striated than in the striated muscular fibre; it is particularly evident in the arteries, causing their contraction when they are emptied of their contents. It is also greatly affected by temperature, being increased by cold, and diminished by warmth. The stiffening of the body after death, called *rigor mortis,* is believed to be due to the tonicity of the muscles, occurring after all irritability has departed, and before putrefaction has commenced. This rigidity is scarcely ever absent, though it may be very slight and of short duration. It does not always commence at the same period after death. When the system, at death, is much weakened or depressed, as in typhus fever, the stiffening comes on early and lasts but a short time; but when death has suddenly occurred in a vigorous person, the irritability of the muscles continues longer, and the rigidity is deferred. It usually commences about seven hours after death, and lasts from twenty-four to thirty-six hours; the flexors are rather more affected than the extensors. The non-striated fibre is more affected than the striated,—particularly the heart and arteries.

The rigor mortis is the last act of muscular contractility; as soon as it ceases, the muscles begin to putrefy. By some it has been attributed to the mere coagulation of blood in the muscles. Bowman has disproved this. Still there are many points of resemblance between the two.

The mechanical application of muscular power in animals is usually unfavourable as regards *power*, but very advantageous as respects the *space* moved over. This is seen particularly in the flexors of the forearm and leg. The *rapidity* of muscular move-

ments is seen in the pulsations of the heart, in the human voice, and in the vibrations of the wings of insects. Of all animals, muscular power seems to be the greatest in Insects, particularly in the beetle tribe.

II. Nervous Tissue.—The possession of a nervous system may be regarded as the characteristic point of distinction between animals and vegetables. Although there are certain plants which exhibit properties very analogous to what is denominated *sensation*, still these are clearly proved to be merely the result of irritability, which can be shown to be an entirely different property from sensibility,—the latter belonging exclusively to animals.

The nervous tissue is composed of a special organic complex material, termed *neurine*, whose function is organico-dynamical, comprising motion, sensation, together with the phenomena of the will and the intellect. Although compound in its nature, neurine is so peculiar in its composition, and so exclusively connected with a special class of functions in animals, that it may be ranked among the proximate constituents of the organism. It has never been discovered in the vegetable kingdom. No very complete analysis of it has yet been made. According to M. Frémy, 100 parts contain 80 of water; of the remaining 20 parts, 7 consist of albumen, 5 of fatty acids, 5 of phosphates of lime and magnesia, 3 of ozmazome, with a trace of peroxide of iron, probably derived from the blood in contact with it.

The fatty acids comprise cholesterine, oleine, margarine, together with two peculiar bodies, *cerebric* and *oleo-phosphoric acids*. The first is solid, white, and crystalline, soluble in boiling alcohol, and forming with hot water a soft gelatinous mass, like starch. It differs from common fats in containing nitrogen and phosphorus; it is a very feeble acid, and forms nearly insoluble compounds.

The oleo-phosphoric acid is procured from nerve-substance by the action of cold ether. It is a viscid fluid, of a yellow colour, insoluble in cold water, and saponifiable. It combines with bases. Boiled for some time in water, it is resolved into oleine and phosphoric acid. The alkalies, in excess, decompose it into glycerine, oleic, and phosphoric acids. On account of its tendency to decom-

position, it must be procured from fresh brain. It is remarkable for containing 2 per cent. of phosphorus.

Liebig has stated that he has procured two other acids from the human brain, soluble in water.

Phosphorus appears to be an essential constituent of nerve-substance. The whole amount of this substance in the brain is eight to ten parts in one thousand, or about one-twentieth to one-thirtieth of the solid matter; it is stated to be deficient in the brains of idiots, and in dementia. The albumen of the brain, in consequence of its union with the fatty matter, forms an emulsion with water.

There are two varieties of neurine—the *white*, *medullary*, or *tubular*, and the *gray*, *cineritious*, *ganglionic*, or *vesicular;* hence, the nervous system may be considered as consisting of two distinct elements,—*ganglia* or centres, and *nerve-trunks* or conductors. The ganglia are sometimes mere enlargements in the course of the trunks, and sometimes distinct central masses giving origin to the trunks. The functions of these two portions are very distinct; the ganglia originate, or send out the nerve-influence, while the trunks merely serve as conductors of this influence. These will be considered separately.

1. The *nerves* or *nervous trunks* are composed of the white or tubular neurine. These consist, each, of a bundle of fibres enclosed in a common delicate sheath, composed of white fibrous matter, and named *neurilemma*. From the interior of this sheath, numerous processes pass down between the different fibres of the trunk, separating them into smaller fasciculi, but at the same time binding them together, and, as in the case of muscular fibre, serving to transmit the nutrient capillaries. The fasciculi of nerves may be still farther divided into the *ultimate nerve-fibres*, which are the elementary forms of nerve-structure. Two forms of ultimate nerve-fibre exist in the higher animals, analogous to the two forms of muscular fibre; one appearing to be the instrument of the animal functions; the other, which is less perfectly formed, being connected with the organic functions. The former of these is distinctly tubular, having a very delicate membranous covering resem-

bling the myolemma of the ultimate muscular fibre. This membranous tube is not penetrated by blood-vessels, but serves, like the myolemma, completely to insulate the contents; and it is believed to be continuous from one end of the nervous trunk to the other. Within this tube is another hollow cylinder of a material known as the *white substance of Schwann*, which differs in its properties from the axis of the tube; this latter is a transparent substance, and is called the *axis cylinder*. This latter portion is believed to be the essential part of the nerve-structure. The whole contents of the tubular sheath are extremely soft, and readily yield to pressure; and the sheath itself varies in density in different parts, being stronger in the nervous cords than in the brain and spinal marrow. It is on account of the greater delicacy of the tubular sheath in the latter, and in the nerves of special sense, that the slightest pressure causes the contents to assume a varicose or beaded appearance, which was deemed by Ehrenberg, who first noticed it, to be characteristic of them. The diameter of the ultimate tubuli varies from the 1-14,000th to the 1-1500th of an inch; but the usual dimensions are between 1-2000th and 1-4000th of an inch. The largest is found in the nerve-trunks; in the brain they diminish as they approach the cortical portion.

The other variety of nerve-fibres is termed the *organic* or *gray*. They are chiefly found in the sympathetic system, and are named *gelatinous* by Henle. They do not appear to consist of the same variety of elements as the former, since no tubular sheath, nor white matter of Schwann can be distinguished. They have a homogeneous appearance, and resemble the non-striated muscular fibre in containing numerous *cell-nuclei*, which may be made to appear by the action of acetic acid, which dissolves the rest of the fibre, leaving them unchanged. The diameter of the organic fibres is usually less than that of the others; it averages, from the 1-6000th, to the 1-4000th of an inch. The term *gray* fibres is derived from their yellowish-gray colour.

Both classes of fibres run continuously from the beginning to the end of the nerve, without anastomosing with each other;—the probability being, that each ultimate fibre has its own distinct

office. The *fasciculi* or bundles of fibres occasionally anastomose with each other; and this may occur either among the fasciculi of the same trunk, or among those of different trunks. The object of such an interchange is evidently to impress upon the different branches the peculiar endowments of any one set of fibres. It is by this means that every branch of the spinal nerves which arises from two distinct sets of roots, is furnished with both sensory and motor fibres. In the same way, some of the cephalic nerves, which arise exclusively either from motor or sensory roots, acquire the functions of the other; and the same union is observed between the sympathetic, which arises from a number of distinct ganglia, and the cerebro-spinal system, which has its origin in the brain and the spinal marrow.

A *plexus* of nerves is the union of the fasciculi of several distinct trunks, for the purpose of a more advantageous distribution. Thus the brachial plexus is composed of the fibres of five pairs of spinal nerves; it sends off five distinct trunks to supply the arm, each trunk, of course, containing fibres from every one of the five spinal nerves. By this arrangement, the liability to paralysis is much diminished, since the functions of the whole five segments of the spinal cord must be suspended before any one part of the arm could be affected. A nerve-plexus may also contribute to a *consentaneousness* of movements.

2. The second element of the nerve-structure is known by the name of *vesicular*, *cellular*, *cineritious* or *gray* substance. It differs entirely from the fibrous or tubular portion, being composed of nucleated cells containing a fine granular substance, and lying somewhat loosely in a minute plexus of blood-vessels. The normal form of these cells is globular, hence they have been termed *nerve* or *ganglion-globules;* but they may become oval or polygonal by pressure. They may also be observed to have one or more processes or peduncles extending from them, giving to them a caudate or stellate appearance. According to Todd and Bowman, who have particularly examined them, these processes are composed of a granular matter resembling the interior of the cell, with which they seem to be continuous. These peduncles may be

traced some distance from the cell, when they are found to subdivide, and also to inosculate with those of other stellate cells; and it is surmised that they may become continuous with the axis-cylinders of the nerve-tubes. The diameter of these globules or cells is between the 1-3000th and 1-2500th of an inch. They also contain, especially in the higher animals, some pigment-granules, which give them a reddish or grayish colour; hence the name *cineritious.* Sometimes each of these cells or vesicles is enclosed in a distinct envelope, composed of smaller cells closely adherent to each other and to the contained cell; this arrangement is found in the inner portion of the cortical substance of the brain.

The vesicular or cineritious substance is found in the centre of the different ganglia, in the interior of the spinal cord of the Vertebrata, and on the exterior of the brain, forming its cortical portion; and likewise upon those parts of the surface or periphery which are destined to receive impressions, as in the expansion of the optic nerve or retina, which contains a distinct layer of nerve-globules; also upon the expansions of the olfactory and auditory nerves, and probably upon the papillæ of the tongue and skin. It is to be regarded as the centre, or originator of all nervous phenomena, whether of motion, sensation, perception, or the higher faculties of reason and thought. It may be distinguished, in man and in the higher animals, from the *tubular* or white portion, by its colour; but this is not an invariable distinction, since the pigment-granules and red blood, to which the dark colour is due, are wanting in the Invertebrata and some others; besides, the gray colour, as we have already seen, belongs also to the organic nerve-*fibres:* the *real* distinction between them consists in their elementary form,—the one being fibrous, and the other vesicular.

The first development of the *fibrous* portion of nervous structure seems to take place, like muscular fibre, by a coalescence of a number of primary cells into a tube; the nuclei of these cells may often be seen between the walls of the membrane and its contents. The nerve-tubes probably undergo but little subsequent change. The *vesicular* structure seems to be produced and regenerated by

a continued succession of cells, like those of the epithelium. Henle supposes that in the cortical portion of the brain, this continued development is going on from the surface towards the centre,—the cells being formed on the surface and carried *inwards*, just as the epidermic cells are carried progressively *outwards*.

The mode of connexion between the fibrous and vesicular portions of nerve-structure is not clearly made out. Mr. Newport has shown that nerve-fibres may enter a ganglion, and come in contact with its vesicles, and then pass out again. The same appears to be the case with some of the fibres that enter the vesicular matter of the brain and spinal marrow. There is a strong probability that the nerve-fibres form *loops* in the vesicular matter; hence, they cannot properly be said to have either origin or termination. This is undoubtedly the case with the fibres entering the peripheric vesicular matter, as the skin. The view, however, taken by Todd and Bowman, would incline to the belief that *some* of the fibres may originate directly from the granular prolongations of the nerve-cells.

In the living state, the neurine is semi-fluid; its solidification after death is attributed to a species of coagulation; by Mulder it is supposed to be owing to a spontaneous separation of the constituents, as of cream from milk.

There is every reason to believe that nervous structure, like the other tissues of the body, is continually undergoing the processes of decay and renovation; and that its waste and disintegration are in exact proportion to the activity of its *functions*. By an unusual demand upon the nervous powers, especially upon the brain—the organ through which the mind acts—a sense of fatigue is experienced, and the necessity for repose or sleep arises, during which nutrition goes on without interruption, and the organ recovers its usual strength. The actual amount of sleep required to restore the nervous system to its normal condition varies in different persons, on account of some difference in constitution; and where, by an effort of the will, the brain is *forced* to a prolonged exertion, and the natural tendency to sleep resisted, both

the bodily and mental health will give way, from the derangement in the nutrition of the organ.

The amount of waste of the nervous system is measured, with considerable accuracy, by the quantity of *phosphatic deposits* in the urine, just as the waste of muscular tissue is represented by the urea. This belief is confirmed by the fact, that no other soft tissue contains any large amount of phosphorus, and also that any unusual demand upon the brain, either by intellectual exertion, or anxiety, is sure to be followed by an increase in the phosphatic deposits. Some interesting pathological facts have lately been made known by Dr. Bence Jones, with respect to the connexion of these deposits and certain disordered conditions of the brain; thus, in acute inflammation of that organ, there is always a proportionate increase of the phosphates in the urine; the same is true also in cases of acute delirium dependent on structural disease,—the phosphates increasing in proportion to the violence of the delirium. Where the delirium is dependent on functional derangement of the brain, as in delirium tremens, Dr. Jones found the phosphatic deposits to be rather diminished.

The nutrition of nerve-tissue must be very active to make up for the constant waste; hence we find it abundantly supplied with blood. This also accounts for the fact that persons of very active minds generally require nearly as much food as those whose muscular system is more exercised, but whose mental exertions are less.

The *regeneration* of nervous tissue is usually very complete, and is familiarly seen in the restoration of motion and sensation in divided parts; and even more conclusively in the production of new nerve-matter, even where there has been a complete destruction of the parts, provided the loss of the nerve be not very great; the removal of half an inch of a nerve, it is asserted, can never be repaired. We are not so well informed as to the degree of reparation of the vesicular substance; but from the known activity of its nutritive changes, there is every reason to believe that its reparation is complete and rapid.

The consideration of the *functions* of the nervous system, and

of its development in different animals, is reserved for the latter part of the work.

That there is an essential physiological difference in the different tissues of the body, is evinced by the well-known fact that the same disease occurring in each, will assume certain peculiar and characteristic features. This is familiarly seen in the case of inflammation, which puts on a different appearance, according to the particular tissue affected. Thus, the areolar and dermoid tissues are especially prone to the phlegmonous form of inflammation, which exhibits such different characters in mucous and serous tissues, that some have doubted the propriety of the term as applied to these tissues. In the former, it is limited and circumscribed by a plastic effusion; but in the latter, it is much more extended, the whole membrane being often involved, as is sometimes seen in the case of the peritoneum or pleura. In mucous membranes there is occasionally a plastic exudation, but not in the encysted form that occurs in the areolar and fibrous tissues. The same is likewise true of the *diffusive* form of inflammation: in the areolar structure it produces a slough, causing great destruction, the tissue coming away in mortified shreds; in mucous membranes no such effects are produced, the inflammation partaking more of the character of erysipelas.

The sclerous tissues are not subject to either phlegmonous, diffusive, or erysipelatous inflammation, but they are very liable to the *scrofulous* form. The fibrous tissues appear particularly prone to the *rheumatic* variety; and the almost universal diffusion of these tissues throughout the body will readily explain the very general extension of rheumatism in the system. The rheumatic form of inflammation rarely gives rise to pus, or to plastic effusions.

It is doubtful whether the true sarcous tissue is capable of inflammation; hence it does not possess the kind of irritability above alluded to; but it is abundantly endowed with the irritability of Haller—the power of contracting under a stimulus; indeed, this is its characteristic property. Inflammation, it is true, will occur in a *muscle*, but only in its areolar tissue, which

is so abundantly supplied to it. Inflammation of the *epithelial* tissues has also its peculiarities: all these tissues are the seats of *catarrh*,—which is characterized by the rapid throwing off of the epithelium-cells before they are completely developed. In the glandular epithelium structures, inflammation gives rise to the various morbid chemical products of secretion. In the *nervous* tissue, the peculiarity of inflammation would seem to be an inability to produce genuine pus, but softening, arising from the formation of exudation-granules, and cells.

The above general description of the tissues, and division into classes has reference to the whole race of man, and of the higher animals. In the human family, however, there are presented many peculiarities of organization giving rise to what is termed *temperament*. The temperaments are usually arranged under three classes: the *nervous*, *sanguine*, and *lymphatic;* to these some add a fourth,—the *bilious*. The *nervous* is characterized by excessive sensibility to impression; great pain is suffered from slight causes, contrasting remarkably with others who suffer but slightly even from disorders of a fatal character,—a peculiarity which may mislead the practitioner in his diagnosis. The *sanguine* temperament is distinguished by the abundance of red blood-corpuscles; hence, the florid complexion, the fulness of the vessels, the liability to palpitations of the heart, and also to hemorrhage and apoplexy. This temperament tolerates depletion well. The *lymphatic* temperament is the reverse of the sanguine. There is a deficiency of red blood-corpuscles; the arteries and veins are small, but the lymphatics or vessels for white blood are proportionally large. This temperament is not liable to open, frank inflammation, but it is much more subject to the scrofulous form, on exposure to cold, or the other ordinary causes of inflammation. The lymphatic glands are also very prone to become enlarged, and, in certain cases, to become indurated.

There are subordinate temperaments connected with the development of particular organs,—as the brain, the lungs, the liver, &c.; each of which will give a special tendency to certain diseases.

It is very rare to find a perfect specimen of any one of these three great temperaments, the organism being generally so nearly balanced as regards its constitutional tendencies, that no very undue preponderance is given to any one. In this way the symmetry of life, or health, is secured.

We have now terminated the analysis of the organism, having considered its various parts separately, under the heads of the primary and secondary forms, both in the healthy and diseased conditions. Its constituent parts, as we have already seen, consists of 1, the organizable material or plasma; 2, the primary and secondary forms; 3, the tissues; 4, the organs; 5, the apparatuses; and lastly, the combination of all the latter to produce the living organism, or economy. The *organs* are the instruments, or operative agents by means of which all the different molecules of the body are supplied with the essential conditions of life—as caloric, oxygen, and a due amount of plasma. The *apparatuses* perform the great functions of life; thus the apparatus of respiration, digestion, locomotion, external sensation, and internal sensation or perception; each performs its allotted function, and each has one common object in view, viz., the *unity of the organism.* This unity of life is brought about in various ways: 1. Although every cell is a distinct organism, and in the performance of its function independent of all other cells, yet they all require certain common conditions of existence, such as plasma, oxygen, and caloric; and these are afforded by the vascular system. This, then, constitutes the first bond of union. 2. The most intimate connexion is maintained between the different parts by means of the nervous system, all of whose parts terminate in one common centre—the cerebro-spinal axis. In man, the medulla oblongata constitutes the *pivot of life;* any injury done to this portion being fatal. 3. Every living molecule and cell is subject to one common force—the *vital force.*

Thus we observe the mutual dependence of every part of the living organism, while, at the same time, each part preserves its independence. If any one of the organs should cease to perform

its allotted office—the liver, for instance, cease to secrete bile—the result would be a derangement of the whole blood, and, as a consequence, of all the other organs also. Hence, while each organ is acting for itself, it is, at the same time, acting for all the others.

In the completed state of the organism, where every part is properly developed, the result will be perfect *symmetry.* This, however, is extremely rare, especially in civilized life, where so many extraneous causes interfere to prevent it. Three kinds of symmetry may be noticed,—the lateral, the sectional, and the antero-posterior. *Lateral* symmetry is distinguished by the correspondence between the two sides of the body, and is marked by its medium line and septa, by the frænum of the lips and tongue, the uvula, and the raphe of the scrotum; also, by the bilateral nervous, muscular, and nervous and glandular systems. The deviations of lateral symmetry are very numerous; it is stated that seventy to eighty persons out of every hundred are defective in this respect. It generally depends upon a deviation of the spinal column, through an unequal action of its muscles; or it may be caused by a deviation of the sternum, the ribs, or the costal cartilages. Frequently there is an unusual development of the præcordial region, which may cause a suspicion of disease of the heart. Again, lateral deviation may be produced as a pathological condition, as where a contraction of one side of the chest results from pleurisy. Deviations in the lateral symmetry of the head and limbs depend usually on an unequal congenital development of the muscles of the two sides. Deviations of *sectional* symmetry are shown by a want of correspondence between the different sections of the body,—as between the cranium and face, between the head and trunk, or between the trunk and extremities. Such deviations may, in some cases, produce a tendency to certain forms of disease; thus, persons of very large development of chest, are supposed to be especially liable to inflammatory diseases of the thorax, whilst those of small and contracted chests are thought to be more exposed to tubercles. Some of these cases may be of a pathological character, as where a disproportion be-

tween the cranium and face results from chronic hydrocephalus; though others of a similar appearance can be clearly traced to an original arrest in the development of the neurine of the brain,—the cranium being distended by the water effused. Deviations of the *antero-posterior* symmetry are much less common than the other varieties; they are caused, usually, by an unequal development of the flexor and extensor muscles.

PART IV.

THE ACTIONS OF THE LIVING ORGANISM.

In the two preceding divisions, we have studied, in all their various details, the *materials* and *forms* of organized beings. The complex machinery of man has been taken to pieces, and each of its parts analytically considered. These separate parts were then put together again, piece by piece, so as to exhibit the organism synthetically. But thus far, the machinery of life has been considered only in a state of rest; we now proceed to notice it under a different aspect, namely, as *the living acting organism.*

Physiologists were formerly accustomed to refer all the actions of living beings to an undefined and inexplicable cause, termed the *vital force.* At the present day this term is used in a much more restricted sense, since the movements of the economy are much better understood. All the actions of the living organism may be comprised under the following heads:—1. Organic or Life-Actions; 2. Chemical Actions; 3. Physical Actions; 4. Dynamical Actions; 5. Mechanical Actions; 6. Psychological or Intellectual Actions. These will now be treated of in their order.

CHAPTER I.

ORGANIC OR LIFE-ACTIONS.

The term *organic* or *life-actions,* implies a necessary connexion with the phenomena peculiar to life; they may hence be de-

fined to be those actions which occur *exclusively* in living beings, being never manifested in the inorganic world. They have already been partially treated of in Part I., under the title of *Vital* or *Organic Force;* it may be proper, however, to allude to them again under the present head. The organic force, as previously explained, is complex in its nature: it consists of the evolution of specific forms from a formless material, and of the moulding and perpetuating these forms according to a model or type. It is witnessed in both animals and vegetables; thus, the material of a fecundated egg is developed into the special forms of the new being; and that of the germinating seed, into those of the young plant. In the first place, there must be a specific material, or protoplasma, for every separate form; but all these various protoplasmata must be derived from the common source—the blood; many of them, however, do not exist in this fluid, as gelatine and neurine, consequently they must be formed from the elements of that fluid by a chemical change. Thus, we see that the very first element in life-action consists in a *chemical* change. The second element comprises the evolution of the primary and secondary *forms* out of this material, by a process confessedly unknown and mysterious. It is to be observed, that these two processes always occur together; and simultaneously with these, occurs the third element of life-action—the production of an organ to perform some special office, according to a type or model. We might also consider under this head, as an element of the life-action, that chemical change concerned in the constant disintegration of the organs, which is so absolutely essential to their very continuance in life. These, however, will be more appropriately spoken of under the succeeding class of actions.

CHAPTER II.

ORGANICO-CHEMICAL ACTIONS.

Until a late period, chemical phenomena were denied a place among the actions of the organism. It is easy, however, to show

that they constitute a very essential portion of the phenomena of living beings, though always under the control of the organic force, and hence termed *organico-chemical.* All the vegetative or organic functions are purely chemical. In vegetables, as already shown in Part II., the very formation of organic matter is a chemical act; water, carbonic acid, and ammonia being decomposed, and their elements again combined to constitute the different vegetable products and tissues, by the agency of the sun's rays. In animals the process is reversed, though it is equally a chemical one,—oxygen being consumed, and carbonic acid being thrown out.

Oxygen is here the great element for decomposition; it attacks the various tissues, combines with their different chemical elements, and thus, by their disintegration, forms the secondary products, such as carbonic acid, water, ammonia, urea, &c., which are thrown off by the excretions.

In the living body, moreover, there is a constant chemical change going on in the conversion of the crude albumen into the various tissues; this principle exists largely in the blood, but is scarcely ever found, *as such*, in any tissue in a normal condition.

The chemical actions are subjected to the controlling influence of the organic or life-force, by which a definite mode of combination is given to the chemical elements, which, if not thus restrained, would produce only the ordinary results of chemical affinity. The same controlling influence is also exerted during life, over caloric and electricity. Now, it sometimes happens that the life-force loses this controlling power, as is often witnessed under great excess or deficiency of caloric, causing, in the one case, the production of a poison in the blood, as is seen in cattle over-driven in hot weather, and in the other, giving rise to an imperfect plasma.

As all the forces reside in the molecules, and, as in *living* molecules, there is superadded to the ordinary forces of inorganic matter the life-force, it is here that the conflict between these forces must take place, and this conflict continues unabated so long as life itself continues.

While the forms of living beings remain persistent, their material is incessantly dying out; and this incessant decay of structure is absolutely essential to the very life of the organ, and likewise to that of the whole organism. Health, then, consists in the harmony between these two great actions. This is exemplified in every one of the functions of a living being; every movement of a muscle is attended with a disintegration of its structure; every act of the mind, every thought that passes through the brain is attended with more or less decomposition of material; and the very amount of exertion of these different organs can be accurately estimated by the amount of product of the excretions. It follows from this that if the supply of food be insufficient to compensate for this incessant decay, there must necessarily be produced a degraded tissue; and in this way, doubtless, many chronic diseases have their origin.

There are two methods by which the effete matters, resulting from the disintegration of the tissues, are eliminated from the economy. The first occurs on epithelial and epidermoid surfaces, which are in contact with the air. These consist of several layers of cells arranged upon a basement-membrane. In their gradual development they push towards the surface, when they either dry up and fall off, just as the withered leaves fall from a tree, as is seen upon the skin, or else they burst open, and discharge their contents, as is witnessed in the mucous membranes,—the remains of the cells being thrown off with the fluid. The second mode occurs in the interior of structures not accessible to the exterior air, as in the muscles, nerves, &c. It is effected by a chemical process through the agency of oxygen introduced by respiration; this combines with the elements of the tissue, forming the various secondary products so often alluded to already, which enter the circulation, to be thrown out by the different excretory organs.

Among the most conspicuous and important of the chemical actions of the economy are to be ranked the functions of Digestion, Calorification, and Secretion. These will be treated of under separate Sections.

SECTION I.

DIGESTION AND FOOD.

ALL organized beings are dependent upon a due supply of aliment or food. In the very earliest states of the new being, this aliment is prepared by the parent; thus, in the seed, the germ occupies but a very small portion, the great bulk being made up of starchy matter designed for nutriment. The same is true of the egg of the animal, the chief portion of which consists of albumen and oily matter, which the germ, in process of development, draws into itself, and uses in the construction of its various parts.

There is a difference between vegetables and animals as regards the *source* of their food. The former have the power of combining inorganic elements so as to form organic compounds; the latter must form their organic compounds from some pre-existing organized body, either animal or vegetable. Animals, strictly speaking, *create* nothing; the materials for their nutrition must be already prepared. These materials may be divided into four classes: 1. The *saccharine* or *amylaceous* group,—including those vegetable substances consisting of oxygen, hydrogen, and carbon, the two former in the proportion to form water, such as starch, gum, and sugar. 2. The *oleaginous* group, including vegetable and animal oils and fats; they are characterized by containing no nitrogen, and only a small proportion of oxygen, but an excess of carbon and hydrogen. 3. The *albuminous* group, comprising the proteine elements both from vegetables and animals, consisting of albumen, fibrine, caseine, &c. 4. The *gelatinous* group, comprising such animal substances as resemble gelatine in composition.

These four groups may be comprised under the two general heads of the *azotized* and *non-azotized* products. The use of the azotized products is for the nutrition and reparation of the animal tissues, and are hence termed by Liebig "plastic elements of nutrition." The non-azotized substances are designed chiefly to supply the materials for animal heat and respiration; these he denominates "elements of respiration."

Animals differ from vegetables as regards the *size* attained. In vegetables the increase may go on to an almost unlimited extent under a due supply of aliment, nearly the whole of which is appropriated to their development; but in animals the full size is soon attained, after which all the nutriment goes to repair the waste of the system. The products of this waste are seen in the excretions; consequently the quantity of food required will be in proportion to the activity of the animal functions.

A second source of the demand for food in animals is the waste occasioned by the exercise of the organic or vegetative functions, which, as has been shown, are accomplished by means of cell-growth. This waste, however, is far less than that produced by the exercise of the animal functions, as in the nervous and muscular tissues. A third cause of the demand for food is the maintenance of animal heat. This process being the result of the combustion of the carbon and hydrogen of the food, with the oxygen of the air taken in during respiration, the quantity required will be, of course, much greater when the external temperature is low, than when it is high. Hence the difference in the appetite in cold and hot weather. The demand for food is likewise dependent on *age*. The large proportional amount required during the period of growth, is not so much for the mere increase of the body, as on account of the rapidity of the interstitial changes which are then taking place. The converse is true of the aged, in whom these changes are much slower; hence, in them, the demand for food is far less in proportion to the bulk of the body, than in the adult, and often even absolutely less than in a child. Any unusual drain upon the system will also increase the demand for food,—thus the secretion of milk, a suppurative discharge, and the discharge in diabetes. There is also a *natural* difference in regard to rapidity of the changes of the system among different persons, producing, consequently, a difference in the amount of food required.

Variations in the food have a greater effect on vegetables than on animals, as regards their size. It is easy to dwarf a plant, by merely transplanting it from a rich to a poor soil, particularly

if the temperature be lowered. But a similar effect is not produced upon an animal, because the corresponding diminution of food would prove fatal to it. Occasionally, however, the influence of this cause is manifested among insects,—particularly during their larva state. An excess of food has not the power to increase the size beyond a certain point; as only a certain amount can be assimilated, the remainder is got rid of as *excretions*. The mere presence of an excess of nutritive matter in the blood, so far from conducing to health, is a source of disease. If fibrine preponderate, the tendency will be to inflammation, if the red globules, to hemorrhage. Besides this, the excretory organs, having an unnatural amount of labour to perform, are liable to become disordered; hence the frequency of disease of the liver and kidney from excess in eating and drinking. The influence of an increased supply of food in the more complete development of an animal is well seen in the case of the *queen-bee*, which is developed from an egg, that, under ordinary circumstances, would have become a *neuter* working-bee, merely by the supply of a richer and more stimulating kind of food.

The only tissue that is increased directly by an excess of food, is the adipose; and this is produced almost entirely from the non-azotized articles—chiefly the oily. The formation of fat only occurs when there is an *excess* in the materials for supplying the process of respiration, and maintaining animal heat. Hence, whatever diminishes this demand for heat, is favourable to the production of fat, and vice versa. In this way, cattle are readily fattened, by being kept at rest in a warm temperature, and fed on oily substances. The great object of the store of fat is for the supply of *fuel* for the maintenance of animal heat. In animals that are starved, the temperature notably sinks just before death; in fact, the immediate cause of death, in such cases, is the great reduction of temperature.

Certain individuals, as well as animals, evince a proneness to the production of fat; in others it is the reverse. These latter are apt to be of the *bilious* temperament. In them, the excess of fatty matter in food must pass out of the system through the

liver, causing a tendency to liver disease. Here it is important to avoid a too fatty diet; or else due exercise should be practised, in order that by the additional respiration, the excess may be *burned* off.

It is impossible to lay down any general law as to the precise quantity of food that is requisite. The average amount, for a healthy adult man taking moderate exercise, may be stated to be from thirty to thirty-six ounces of dry aliment a day; but much less may suffice. The value of different sorts of food depends upon the quantity of *solid matter* they contain, upon the proportion of *digestible materials* in these solid matters, but chiefly upon the *chemical composition* of the substances,—those only which contain nitrogen being nutritious, and are hence appropriately named by Dr. Thomson *nutritive elements;* the non-azotized being called by him *calorifacient elements.* Gelatine alone cannot support life; but it is useful to repair the waste of the gelatinous tissues; if it be withheld, these tissues must be supplied by the transformation of the proteine compounds. There is no proof that gelatine is ever converted into any of the proteine compounds. Vegetables abound chiefly in the non-azotized products, as sugar, starch, and oil. Those which contain most of the azotized materials are the leguminous plants, which are known to be the most nutritious. The great use of the non-azotized articles, as before said, is to supply materials for respiration and animal heat. In the *oily* matter there is a great excess of hydrogen and carbon, both of which combine with oxygen taken in by respiration, and contribute to supply the heat. Hence it is that the inhabitants of the frigid zone make use of so much oil and fat in their food, by which they are enabled to sustain the extreme cold of their climate. Nearly all the saccharine matters of the food are very soon carried off by the process of respiration, scarcely ever reaching the general circulation.

The diet best adapted to man is one containing a due admixture of the azotized and non-azotized materials. This is just the case in *wheaten bread*, which is so universally employed. The mere *farinaceous* articles, such as rice, potatoes, &c., which contain so

little proteine mattter, cannot properly support life, unless a large quantity be digested, and the persons lead an inactive life. The use of *meat*, to any extent, is rather injurious, unless accompanied with a very active life. *Milk* contains a mixture of saccharine, albuminous, and oleaginous materials, and is hence well adapted to the nutriment of the young animal. It is said that the milk of the carnivora contains no sugar.

It is impossible for an animal to be nourished upon any *single* alimentary substance, no matter how nutritive it may be, on account of the disgust which long continuance always excites. The same is true of man. Certain inorganic substances are also required in the food,—as *chloride of sodium*, for the muriatic acid in digestion, and for the soda in the blood; *phosphorus* as a constituent of nerve-structure, also in the composition of bones (phosphate of lime), and in some of the secretions in the form of acid and alkaline phosphate of lime and soda; *sulphur* in some of the tissues; *lime* in bones and shells; *iron* in the hæmatine of the red corpuscles of the blood. All these substances are found in the common articles of food: if they be withheld, the function of nutrition will be incomplete.

Varieties in the Digestive Apparatus.—The aliment of animals differs from that of vegetables in being required to undergo the process of *digestion*. The object of this process is threefold:—the reduction of food to a fluid form; the separation of that portion which can be absorbed from that which cannot; and a certain change which is undergone by the former to prepare it for future use. The simplest conditions for accomplishing these purposes are the presence of a fluid to act as a solvent, a fluid capable of acting as a precipitant to separate the excrementitious from the nutritive, and a cavity, or *stomach*, where these processes can be performed.

In the lowest animals, as the hydra or fresh-water polype, the stomach is only an inversion of the skin, having but a single opening. The solvent fluid, or *gastric juice*, is secreted by the walls of this cavity, and acts upon the food when taken in; the

nutritive matter is absorbed from the walls of the cavity, and the effete portion thrown out by the same orifice. In animals a little higher in the scale, the stomach is continued into a canal, which has its appropriate exterior opening—the anus. The gastric juice is secreted as before; but *bile* begins to make its appearance, being furnished from follicles in the stomach. Still higher in the scale of animal life, the digestive organs become more complex, though never differing in their essential character; the teeth being added for mastication, and the salivary glands for insalivation.

Among higher animals, the true digestive process takes place in the stomach and upper portion of the small intestines. The shape of the former varies with the character of the food; when this is of so simple a nature as easily to be acted upon by the gastric juice, the stomach is only a simple enlargement of the alimentary canal; this is the case with animals that feed chiefly upon blood, as weasels, &c. But where the food has to undergo much change, the stomach forms a considerable enlargement, as in the herbivora. In man, the form is intermediate between the two. The admixture of the bile with the food takes place after the latter has quitted the stomach.

The intestinal canal is added for the purposes of completing the changes which the food must undergo, before all the nutritious portions can be absorbed. Its length corresponds with the character of the food. Thus, in the carnivora, whose food is easily assimilated, it is comparatively short. In the herbivora, on the contrary, it is extremely long;—in the sheep, it is twenty-eight times the length of the body. In man, whose diet is of a mixed nature, the alimentary canal is about thirty feet long, or about five or six times the length of the body. The intestine is divided into small and large. The small intestine, in man, constitutes about five-sixths of the whole. Its mucous membrane is arranged into folds, called *valvulæ conniventes*, the object of which is to extend this surface for the increased lacteal absorption, by means of the *villi*, in which the lacteals originate. There are no valvulæ conniventes in the large intestine, and but very few villi.

The different secretions of the alimentary canal are spoken of elsewhere.

Action of the Mouth and Œsophagus.—The *prehension* of the food is usually entirely voluntary; but in the infant and some of the lower animals, it seems instinctive, as in the grasping of the nipple.

The object of *mastication* is to triturate the food and mix it with saliva. We are chiefly indebted to M. Bernard for a knowledge of the true function of the saliva in the digestive process. That physiologist found that during mastication the flow of saliva was almost entirely confined to the duct of the parotid and sublingual, the secretion of which is clear and limpid; but that, during deglutition, the secretion of the sub-maxillary, which was thick and viscid, was the greatest. He hence inferred that the mechanical use of the former was chiefly to saturate the food, and so assist mastication, while the latter, from its glutinous properties, aided deglutition. In regard to its chemical action upon starch, converting it into grape-sugar, it is very questionable if *ptyaline*—the peculiar principle of saliva—exists at all in the large salivary glands, since both Magendie and Bernard ascertained that neither the secretion of the parotid, sublingual, nor sub-maxillary, either alone or combined, have any effect upon amylaceous matter; but yet that the mixed saliva of the mouth unquestionably has; whence they concluded that the ptyaline was principally, if not exclusively, secreted by the buccal glands. The nature and properties of ptyaline have already been noticed (Part II., *Proteine Compounds*); it will be sufficient to remark here, that Mialhe's notion that this principle effected the digestion of amylaceous matters by converting them into grape-sugar was shown by Bernard to be erroneous, since, in the first place, the contact of an acid, as the gastric juice, at once destroys its power; and further, that although, if permitted to remain long enough in contact with amylaceous matters out of the body, it would convert them into dextrine, glucose, lactic and butyric acids, yet, in digestion, it effects but little transformation, owing to the brief period of contact. Besides, this digestive power is

not peculiar to the ptyaline, since many other organic substances possess it. The saliva, then, has probably but little other effect than to assist mechanically in mastication and deglutition; the true digestion of the amylaceous matters taking place by the intestinal fluid converting them into glucose.

The nature of the *teeth* varies in different animals. In the carnivora they all have sharp cutting edges, and move perpendicularly upon each other, so as simply to divide the food. In the herbivora the arrangement is favourable for great lateral movement of the lower jaw, and the molar teeth are very rough, for the purposes of *grinding* the food. In man both objects are attained: the conformation of his mouth and teeth evidently showing that he was designed for a mixed sort of diet. A proper mastication of the food is of great importance to healthy digestion. Rapid eating is a frequent cause of dyspepsia, the stomach not being able so well to act upon imperfectly chewed food. When the food is thus properly comminuted, it is carried backwards to the fauces, and then into the pharynx, by the act of *deglutition*. The tongue conveys it as far as the anterior palatine arches; these contract and close over the tongue so as to prevent the return of the bolus; and at the same time the posterior nares are closed by the junction of the posterior palatine arches with the uvula. The larynx is drawn forwards, and the epiglottis pressed down over the rima-glottidis, so as to prevent an entrance into it. In this way a sort of inclined plane is formed, down which the morsel slides, when it is seized by the constrictors of the pharynx, and so propelled down into the œsophagus. Deglutition is an *involuntary* act,—of a reflex character.

The propulsion of the food along the œsophagus, is effected by the peristaltic contraction of the muscular coat of the latter, under the *direct contact* of the food. It is neither due to the will, nor to the reflex action of the spinal cord, since it occurs when all nervous communication is cut off. The contractions of the œsophagus take place in a rhythmical manner; but as the stomach becomes full, the intervals are longer. In *vomiting*, the peristaltic actions of the œsophagus are reversed; and this reversion

has been observed even after the separation of the stomach from the œsophagus, as a consequence of injecting tartar-emetic into the veins. At the cardiac orifice of the stomach, where it is joined by the œsophagus, there is a sort of sphincter muscle, which is usually closed, but which opens by the pressure of the food upon it, and then closes so as to retain it. This closure is due to reflex action, for when its nerves are divided, the sphincter no longer closes, and the food regurgitates into the œsophagus. The opening of the cardia is one of the first acts in vomiting.

The stomach of ruminant animals consists of four separate cavities, communicating with one another. The œsophagus does not terminate in the first of these, or the *paunch,* but continues onwards as a deep groove with two lips, which by closing, form a tube, which serves to convey the food into the *third* stomach. The food as first swallowed is but slightly masticated, and reaches the termination of the œsophagus in a dry, bulky state. This separates the lips of the demi-canal, and passes into the first and second stomachs, where it becomes macerated in the fluids of these cavities. It is then regurgitated into the mouth by a reverse peristaltic movement of the œsophagus, in a regular succession of rounded masses. It is now thoroughly masticated and mixed with saliva, (the "chewing of the cud,") after which it is swallowed in a pulpy state; being carried along the demi-canal, without opening the lips, into the *third* stomach, and thence into the *fourth,* where alone true digestion takes place.

Action of the Stomach—Chymification.—The chief object of the stomach is for the purpose of submitting the food to the solvent action of the *gastric juice.*

When the food has reached this cavity it is subjected to a peculiar peristaltic movement. This is produced by the contraction and relaxation of the various fasciculi of the muscular coat; it causes a complete revolution of the contents in every direction, and a consequent thorough trituration. Towards the end of the process, a sort of hour-glass contraction takes place, about four inches from the pylorus, by a shortening of the transverse fasciculi. The fluid portion is received into the smaller or pyloric end, while the

solid portion is retained in the larger end until it is completely dissolved.

It is not certain how far these movements are under nervous influence. They are found to continue even after the section of the par vagum, although the first effects of the operation are to suspend them. On the other hand, irritation of the par vagum has been found to produce these movements when the stomach was full, but not when empty. The mucous membrane, when minutely injected, exhibits, under the microscope, some modification of its structure in its different parts; by far the larger portion presents the usually-described honeycomb structure, consisting of cells or alveoli, surrounded by capillaries; their walls, also, being composed of a capillary network, which subdivides the cell into smaller ones. These cells are what are usually considered to be the orifices of the gastric glands; their diameter is from the 1-100th to 1-250th of an inch. Into the bottom of each alveolus several gastric follicles are generally described as opening; these are, however, in reality, only the minute subdivision produced by the capillaries distributed there. Close to the pylorus the membrane assumes the appearance of conical *villi*, as described by Dr. Neill, and becoming larger and more numerous about the pyloric valve, so that fewer of the angular or polygonal cells are visible in the interstices. These villi, though rather smaller than those of the small intestine, appear to resemble them in many points; so much so, as probably to justify Dr. Neill's supposition, that their *function* may prove to be in some manner connected with digestive absorption.*

The *gastric juice* is a secretion of the walls of the stomach; it is only found during the presence of food, or when the stomach is irritated by some solid body. In the intervals between digestion, the mucous membrane is of a delicate pink colour, of a velvety appearance, and covered with mucus. Under the stimulus of aliment, it becomes turgid with blood, and numerous minute papillæ are seen, under the microscope, to erect themselves so as to rise

* *Vide* Dr. Neill's paper in Summary of Trans. of Phil. Col. of Phys., Nov., 1850.

above the mucus covering the surface, from which a limpid, colourless, slightly viscid, and acid fluid distils;—this is the gastric juice. It is secreted (through the agency of cell-growth) by the follicles, or minute subdivisions produced by the capillary rete in the bottom of the depressions, above described. Bernard's experiments make it to come principally, if not exclusively, from the membrane around the pylorus.

The chemical composition of the gastric juice is not definitely determined. That of man has been found to contain free muriatic, acetic, and lactic acids, to either of which its acid reaction may be due. Blondlot's experiments go to show that the gastric juice of the dog contains neither of these acids, but that the acid reaction is due to the superphosphate of lime; this is, however, denied by Bernard and Dumas; the former believes that *lactic acid* is the only free acid in the gastric juice.

The gastric juice has the power of coagulating albumen to a great degree; it is also highly antiseptic. Its peculiar properties are due to an organic principle named *pepsine*, or *gasterase*, analogous to albumen in composition. This principle is soluble in cold water, but not in hot water. It combines with some of the acids, forming compounds which still redden litmus paper. It is chiefly remarkable for its great solvent power over albuminous substances. Artificial digestion may be caused, out of the stomach, by the action of a due admixture of dilute muriatic acid and pepsine upon various alimentary substances,—the whole being kept at a temperature of 98° F. If the acid be used *without* the pepsine, no effect is produced at the above temperature; but at the boiling point, solution takes place, presenting the same characters as when pepsine was used at the temperature of 98°. From this it appears that the acids are the real solvents; the pepsine being thought to serve as a ferment, or more properly, by *catalysis*, producing some change in the substances on which it acts, disposing them to be dissolved by the acids, and replacing the effects of a high temperature, such as would not be compatible with the safety of the stomach. Pepsine undergoes no change itself in the digestive process, and forms no combinations with the substances upon which

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it acts. Hence, stomachic digestion may be considered as the result of chemical solution. It is a *vital* process only so far as vitality is necessary for the secretion of the gastric juice.

The quantity of food which the gastric juice can dissolve within a given time, is limited. *Cold* retards the digestive process, hence the use of much cold water or ice at meals, must be injurious.

The quantity of gastric juice secreted, is not so much regulated by the amount of food ingested, as by the wants of the system. Hence an excess of food, not being dissolved, will act as a source of irritation to the stomach. Condiments, as pepper, mustard, &c., act by gently stimulating the mucous membrane to increased secretion. If the irritation of the membrane be continued, it becomes red and dry, the epithelium is abraded, irregular dark patches are seen, together with aphthæ. These changes are indicated by dryness of the mouth, furred tongue, accelerated pulse, and other evidences of fever. The emotions sometimes produce similar effects; those of a depressing nature occasion a pale flaccid condition of the membrane. The positive influence of the pneumo-gastric nerve over the secretion of the gastric juice may be regarded as proved by M. Bernard: on cutting this nerve in an animal, into whose stomach a canula had been previously introduced, he saw the mucous membrane, which had just before been tense and turgid, become withered and pale, and the gastric juice cease to flow.

From experiments made by Dr. Beaumont upon different articles of food, by gastric juice taken from the stomach, it appears that the flesh of wild animals is more digestible than that of the domesticated, probably from the less proportion of fat which it contains. Beef is more digestible than mutton, and mutton much more so than veal and pork; poultry is not so digestible as was supposed; cabbage in the raw state, has been found to be far more digestible than when boiled. These statements cannot be received as indicative of the actual *digestibility* of different substances, since the fact of their disappearance from the stomach is no proof of their having undergone complete digestion.

The food, when thus acted upon by the gastric juice, receives

the name of *chyme*. Its consistence varies with the relative quantities of solids and fluids ingested. Usually, it is of a grayish colour, homogeneous, semi-fluid, and of a slightly acid taste. When the food has contained much oily matter, the chyme has the appearance of cream; when the diet has been farinaceous, it resembles gruel. The following is believed to be the condition in which the various alimentary principles exist in it: the proteine-compounds, whether animal or vegetable, are reduced, according to Mialhe, to *albuminose*—a compound resembling crude albumen, a part of which is dissolved, and a part held in suspension; gelatine will be dissolved, or not, according to its previous condition; if found in a tissue, from which it cannot be easily extracted, it will pass on, nearly unchanged; vegetable gum, if of the soluble form, is dissolved, as in the case of arabin, pectin, and dextrine; starch, when its vesicles have not been ruptured by heat, is sometimes broken down and dissolved, as by the ruminants, and the granivorous birds; sometimes it passes through the alimentary canal unchanged; the amylaceous substances generally, as before pointed out, undergo but a very limited digestion, until they have passed into the small intestine; sugar is dissolved when the stomach is in a healthy condition; oily matters pass unaltered into the duodenum, where they are acted upon by the pancreatic fluid, and converted into an emulsion. Many other substances, as lignin, resins, horny matter, &c., pass through unchanged, and are discharged among the fæces, as entirely useless.

Action of the Intestinal Tube.—The passage of the chyme through the pyloric orifice is at first slow, but it becomes more rapid as digestion progresses. From this time it is propelled onwards by the simple peristaltic action of the muscular coat, which is excited by the immediate stimulus of the chyme, or of the secretions which are mingled with it. Its independence of nervous influence is seen from the fact that it will continue when all nervous communication is cut off, and from the difficulty of exciting contractions by stimulation of the nerves. The influence of the emotions upon this movement is probably exerted through the sympathetic, which supplies the whole intestine.

In the duodenum the chylous fluid is mingled with the secretions of the pancreas and the liver. It is only within a few years that the true function of the former has been satisfactorily demonstrated by M. Bernard. By numerous experiments, this physiologist has shown that the pancreatic juice is the efficient cause of the digestion of fat. When fatty substances of any nature were put in contact with it, an *emulsion* was immediately formed which did not again separate on standing; whereas all mixtures formed with fats and any other fluid of the body—even with pure bile—very soon separate when in repose. Previous experiments made with the bile of animals had obtained a similar result of making an emulsion with fats: but this was clearly shown to have been owing to the admixture of some of the pancreatic fluid with the bile employed. The fatty materials of the food were observed to undergo no change in the intestine of the rabbit (in which animal the pancreatic duct opens considerably below the hepatic,) until they passed the pancreatic orifice, when the characteristic milky appearance of the contents of the lacteals immediately took place. The oily matters, in all probability, ultimately undergo change into glycerine and the fat acids, though these have never been detected in the blood; fat being always found neutral in the economy. Bernard ascribes the peculiar action of the pancreas to an albuminous principle, which he has isolated, and named *chylopoine*. The pancreatic fluid has also the property, in common with many others, of converting amylaceous substances and cane-sugar into glucose.

As regards the part performed by the *bile* in the digestive process, it would appear that, by being mixed with the gastric juice, it prevented fermentation and arrested the process of putrefaction, thus regulating the escape of gases; but still more important, that when mingled with the pancreatic fluid and the secretion of the muciparous glands in the duodenum, it constitutes the true *intestinal fluid*, which is a perfect solvent for *all* kinds of food. A more complete digestion, in fact, takes place in the upper portion of the intestine than in the stomach itself.

The secretion of bile is of great importance, not only for the

separation of certain matters from the blood, but also for the perfection of the digestive process. This is the obvious reason for the liver discharging so high up in the intestine. If the bile-duct be divided, so as to allow the bile to flow out by a fistulous opening, the animal will die of inanition. Again, if the duct be tied, constipation always occurs, in consequence of the want of stimulus to the peristaltic action. It is by stimulating the biliary secretion, that mercury acts as a *purgative*.

Although the liver is *constantly* secreting, the bile only flows into the duodenum when there is chyme present. When not needed, it accumulates in the gall-bladder. Hence the gall-bladder is always found turgid in persons dying of starvation. The flow of bile into the intestine is imputed to the pressure of the distended duodenum upon the gall-bladder; but it is probable that the peristaltic action of the muscular (middle) coat of the ductus choledochus may be excited, either through the sympathetic nerve, or by irritation at the orifice of the duct, as in the case of the salivary glands.

After the food has passed the orifice of the ductus choledochus, the nutritious portion begins to be taken up by *absorption*, leaving the excrementitious matter, which is increased by the products of the secretion of the different intestinal glandulæ. The nature of these secretions is treated of in another place. The cæcum in some animals is quite large;—occasionally there are two cæca. The secretion of the cæcum in herbivorous animals is acid during digestion, and their food is believed to undergo there a second digestion; this is not the case in man.

The act of *Defecation* is chiefly reflex, though partly voluntary. The retention of the fæces is due to the contraction of the sphincter ani muscle. The action of this muscle is mostly reflex. Its power is lost, if the nerves be divided, or in injury to the lower part of the spine. If the mucous membrane be unduly excited, the muscles of defecation (diaphragm and abdominal muscles) will, by reflex movement, be caused to act frequently, and overcome the contraction of the sphincter.

Hunger and Thirst.—The sensations of Hunger and Thirst

are instinctive, being intended as guides in the reception of food and drink.

The sense of hunger is usually referred to the stomach. It is not caused by mere emptiness of that organ, since if the previous meal has been sufficient, no hunger is produced, though the stomach be empty. It is not due to the action of the gastric juice upon its coats, as has been supposed, since this fluid is only secreted under the stimulus of food; neither is it owing to the distension of the gastric follicles. The probability is that the *general want of the system* is the remote cause, acting through the medium of the sympathetic nerve. Under this influence, there is a determination of blood to the stomach, which may be the *proximate* cause of hunger, by acting upon the par vagum nerve. When food is taken into the stomach, the secretion is excited, and the capillaries unloaded. The sensation is removed by introducing nutriment into the system in *any* mode. It is also abated by the section of the par vagum. A certain degree of *bulk* seems necessary to excite the proper amount of secretion. The sense of hunger is much influenced by the mental emotions. It may also exist without the mind taking cognizance of it, on account of its being pre-occupied,—as is seen in hard students.

The sense of Thirst indicates the general deficiency of fluids in the system. The *immediate* seat of the feeling is the fauces. It is relieved by introducing fluid into the system by *any* mode, as by the rectum, skin, &c. In the same way, it may be excited by diarrhœa, perspiration, or any other excessive loss of fluid; also by certain kinds of spicy food.

The feeling of Satiety is not produced by the mere fulness of the stomach, but by the *general* feeling of the system, from the absorption of the nutriment.

SECTION II.

CALORIFICATION OR ANIMAL HEAT.

The maintenance of a proper animal temperature is one of the most important of the functions of the living body. It is, in fact,

the standard by which we judge of the internal organic actions of animals. Heat subserves two very important purposes in the animal economy; *first*, it is indispensable for the production of the various protoplasmata out of the common plasma—albumen, and also for the evolution of forms under the influence of the germ-force; and *secondly*, it developes mechanic power in the muscular system, by being converted into the nerve motor-force, through the medium of the nerve-centres.

As has already been shown, a certain amount of heat is one of the requisites for vital action. There is a great difference, however, among animals, as to the amount of heat most favourable for the performance of their functions, and also as to their power of generating it in themselves. The invertebrata are generally *cold-blooded*, that is, have little or no power of sustaining an independent temperature. The energy of their vital actions depends upon the temperature of the external medium; when this sinks below a certain point, they pass into a state of torpidity. The same thing is true of most fishes and reptiles, though not universally.

The classes of animals most endowed with the power of generating heat, are insects, birds, and mammalia. As regards insects, this power varies very much in their different conditions; thus, in their larva and pupa states they may be considered cold-blooded,—their temperature rising and falling with the external medium. In their perfect state, however, which is one of great activity, their temperature is many degrees higher; and this is remarkably increased when numbers of them are crowded together, as in a bee-hive. The temperature of birds is higher than that of any other class of animals,—varying from 100° to 112°. The lowest degree is found in the aquatic species, as the gull; the highest, in those most active in flight, as the swallow. The temperature of the mammalia ranges from about 96° to 104°; that of man, from 96½° up to 102°. The variations are dependent, in part, upon the temperature of the surrounding air, but they are also influenced by the general condition of the body, as to repose or activity, the period of the day, the length of time after eating,

&c.;—thus, a larger amount of caloric is generated during the day than in the night; there is also a slight increase during the digestion of a meal, and a very sensible increase by exercise. Disease often causes great variation of animal temperatures: it is increased in those conditions where the respiration and circulation are very rapid, as in the last stages of phthisis, in hypertrophy of the heart, but particularly in scarlatina and typhus fever, in which it has attained the height of 106°; and in a case of tetanus, of 110¼°. It falls in spasmodic asthma to 82°, and in Asiatic cholera, and cyanosis to 77°. The degree of moisture of the surrounding medium has an effect upon the temperature of the body: thus a heated atmosphere of 350° and upwards may be borne, provided it be dry, so as not to prevent evaporation from the surface of the body. Experiments on animals go to prove that the body cannot be raised more than from 11° to 13° beyond its natural temperature, without producing death.

The *source* of animal heat was at one time referred to the nervous system, but it is evidently due to the organic, and not to the animal functions, since heat is evolved by vegetables, particularly from the leaves and stems, in which the most active vital changes are taking place; but most of all during the flowering season: thus a thermometer placed in the midst of five spadices of the *Arum* rose from 66° to 111°, and one placed in the midst of twelve spadices, rose to 121°. The same rise of temperature is seen in the germination of seeds, as in the process of *malting*, when the thermometer has been seen to rise to 110°. The peculiar changes which cause this elevation of temperature consist in the combination of the oxygen of the air with the carbon of the plant,—it being, in fact, a slow combustion or oxidation, so that an amount of carbonic acid is formed and set free, just as in the respiration of an animal. The reason why it is not commonly observed is because the process is slowly performed, and concealed by a converse change—the *fixation* of the carbon from the carbonic acid of the air, by the influence of light. It has been ascertained by careful experiment, that the amount of heat generated is in exact relation with the amount of oxygen absorbed

and of carbonic acid set free: thus, if the plant be put into an atmosphere of nitrogen or hydrogen, no heat is evolved; but if it be placed in pure oxygen, the elevation of temperature is greater than usual.

The mode of the production of heat in animals is precisely similar, being the result of a slow combustion or oxidation; the *fuel* consumed being chiefly the carbon and hydrogen of the food. The food destined for the support of life consists of two distinct classes of materials,—the one containing nitrogen, and destined for the support of the various tissues of the body, and hence termed the *nutritive elements* of food; the other consisting only of carbon, hydrogen, and oxygen, and destined by their slow combustion or oxidation for the production of animal temperature, and hence appropriately named the *calorifacient elements.* The proportion of these two classes of aliment in the food of man, as presented by nature, is remarkably unequal,—the non-azotized constituting nearly seven-eighths of the whole. From numerous experiments, it has been ascertained that the food of an adult man must contain thirteen to fourteen ounces of carbon, per diem; while two to three ounces of nitrogenized aliment will suffice for the reparation of the waste of the tissues. According to Lavoisier, a healthy adult man consumes, in a year, 746 pounds of oxygen by respiration; another estimate makes it 837 pounds; allowing a consumption of thirteen ounces of carbon a day, and three ounces of hydrogen, in the form of food, the amount of hydro-carbon, or *fuel* derived from these sources, used up in a year, would exceed 360 pounds. The excess of the hydro-carbon, not required for animal heat, is stored away in the form of fat, to be ready in cases of emergency. Hence, in emaciation, the fat is always the first to disappear; and in starvation, the *immediate* cause of death is cold, as satisfactorily shown by the experiments of M. Chossat, already alluded to.

The intimate connexion between the nature of the food, and the production of heat, is familiar in the instinctive fondness evinced by the inhabitants of very cold climates for an aliment rich in hydro-carbons; the partiality of the Greenlander, or Esqui-

maux for whale-blubber is well known. On the other hand, fatty food is as instinctively avoided by the inhabitant of the tropics, because he is not compelled to produce so much animal temperature. A still farther confirmation of the doctrine may be derived from the pathological condition. Individuals are frequently found whose food is habitually deficient in the calorifacient elements; such persons are very apt to suffer from various nervous symptoms, more especially, if their temperature be reduced still lower by an insufficiency of warm clothing. Whenever the temperature of the body remains permanently below 98°, the actions of life cannot be performed in their usual manner; an imperfectly-elaborated plasma must result, and as a consequence, an unhealthy organization, with a special tendency to the production of scrofula. We find in all warm-blooded animals provision made for exposing the blood to the influence of the oxygen of the air, and also a constant proportion between the amount of oxygen consumed, of carbonic acid generated, and of heat evolved. The union between the carbon and oxygen must occur *throughout the system*, and not in the lungs, as has been maintained. It appears, however, that the whole quantity of caloric generated in a given time is greater than could be evolved by the combustion of the carbon of the carbonic acid given out during the same time: hence, there must be other chemical changes going on; one of these may be the union of some hydrogen with the excess of oxygen to form watery vapour; another source is, probably, from the union of oxygen with the sulphur and phosphorus of the food; also, perhaps, from the production of urea from the proteine compounds.

From experiments on animals, it is ascertained that the *skin* performs an important part in the aeration of the blood, and the maintenance of animal heat. If the skin be entirely coated over with a varnish, the temperature is remarkably lowered, and the animal dies.

The power of maintaining animal heat is much less in young animals than in the adult; the same is true of man, the human infant being more dependent in this, as in other respects, than

any other animal. It has been ascertained, that during the first month of infant life the mortality in winter is nearly double that of summer; and the difference is attributable to the inability, at that age, to resist the effects of cold. As age advances, this disproportion decreases, till it nearly ceases at adult life; but it again appears in declining age; and at ninety years, the average mortality of winter is much more than double that of summer.

There are certain sensations of heat experienced by the system, which are entirely dependent upon nervous derangement; in this respect they are analogous to the sensations of cold, or the chill which precedes a fever. The cause of what is termed *fever-heat* has not yet been satisfactorily explained. It cannot be due to the same source as that which produces ordinary animal temperature, since the supply of food is usually entirely cut off by the loss of appetite. It arises probably from the oxidation of the tissues; this will account for the rapid disappearance of the fat, and the excessive emaciation so often observed in protracted fevers. There is also this remarkable difference in the *result* of the production of heat in the two cases: in health, as we have seen, the increase of temperature is accompanied by an augmentation of mechanic power, or strength; in fever, on the contrary, there is a remarkable prostration of all the dynamic powers. This has been ascribed by Prof. Jackson, with much plausibility, to the presence of some morbific matter in the blood, acting possibly as a ferment, and so impairing its crasis as to prevent its exerting its natural healthy stimulant influence upon the nerve-centres.

SECTION III.

SECRETION.

The term Secretion literally signifies *separation*, which in fact is nearly its physiological meaning. Its essential character is identical with that of nutrition, as each is merely a process of cell-growth. While the cells of nutrition separate certain mate-

rials from the blood, to deposit them in the various tissues of the body, the cells of secretion, which always communicate with the external surface, separate matters which are designed either to be thrown out of the system altogether,—as the urine, or to subserve some future purpose in the economy,—as the bile and gastric juice. The term *excretions* is generally given to the former products, and the term *secretions* retained for the latter. The excretions are made up from the decay and decomposition of the several parts of the system: they must be separated from the blood as fast as poured into it, or else they act as poisons to it, as witnessed in the case of urea, or biliary matter.

The other class (true secretions) vary but little in composition from the materials of the blood; they are separated, not so much to maintain the purity of the blood, as to supply some future want of the system; for example, the suspension of the secretion of gastric juice interferes only with the function of digestion, but does not poison the blood. The secretion of milk differs from other secretions, in not being designed for use in the economy of the individual, but to afford nutriment to a separate being.

Although the essential instruments of secretion are merely epithelial-cells, yet we usually find special organs set apart for the function, denominated *glands.* A gland is nothing more than a collection of follicles closely packed together for the sake of economy of space. The follicles contain the true secreting cells in their cavities: any one of them may be regarded as an epitome of the whole gland. The secreting cells draw their materials from the surrounding capillary rete by endosmose. The character of the secretion is not at all influenced by the *form* of the gland. As a proof of this, every variety of structure for the secretion of bile and urine, is found in the different grades of animals,—from the simplest follicle, to the most complete gland: in every case, however, the ultimate cell (the true secreting organ) is the same. The *act of secretion* consists in the cells absorbing from the blood their proper materials, then swelling up, bursting, and discharging their contents into the excretory duct. We are ignorant of the reason why one set of cells should separate urine, another set, bile,

&c.; it is attributed to a selective power resident in the cells, or rather in their nuclei; but this is no explanation; it is a *law* impressed upon their nature, and must be received as an "ultimate fact" of science.

Difference in the structure of Glands.—In the lowest order of development, the mere rudiment of a gland is discoverable, in the form of a simple depression or crypt. A little higher in the scale, we find a tube lined with an epithelium; still higher, we meet with an assemblage of cæcal pouches, terminating in a duct. In the very highest developed glands, as the kidney and testicle, the arrangement consists of convoluted tubuli of very great length, but closely packed together for economy of space, and securing, at the same time, great extent of surface. It has already been explained how each one of the animal cells is a separate and independent organism; this is especially true of the cells engaged in the process of secretion. Although the myriads of cells composing a gland are all occupied in one and the same office, yet each one is acting for itself, and by itself; this will explain the reason why a gland may continue to secrete even when a considerable portion of it is in a diseased condition; this often occurs in the liver.

There is, then, no real distinction between secretion and nutrition. The *nutrition* of a gland is its act of secretion, since each epithelial cell lives and grows by receiving within its walls the materials which constitute its secretion.

Secretion is generally accompanied by *exhalation*, which is often improperly confounded with it. Exhalation is merely the transudation of fluids through the porous substance between the cells; the true secretion is solid, or nearly so. Thus, in the kidney, the real secretion consists of the separation by the cells of the tubuli uriniferi, of the urea and uric acid; but at the same time a large supply of water is drained from the blood through the Malpighian bodies, which allow the fluid thus separated to pass into the tubuli, and wash down the secreted matters into the ureters.

The complete suppression of urine in cholera affords an excellent illustration of the same fact. In this disease, the tubuli of the

kidneys are found filled up with a tough, whitish matter; this is the true secretion, which, however, could not escape, simply from a want of a due supply of water, which had been drained off by endosmose into the bowels. On the other hand, it is often noticed that a paroxysm of hysteria, in women, is attended with a copious discharge of pellucid urine, almost like water; this is caused by a sudden filtering through the tufts of Malpighi.

Nature of Secretion.—Two views are maintained,—one, that it is a mere separation of matters pre-existing in the blood: this would make it a physical process; the other, that the elements are separated from the blood, but combined in the cell so as to constitute the true secretion: this view regards it as a chemical process. The latter doctrine is most probably the correct one. The bile, for example, does not exist, *as such*, in the blood; neither does the urine, though the *materials* of both are found there: the *recombination* takes place in the cell. The question is not yet settled, whether the different materials of the same secretion are separated by the same cell, or whether each material has its own special cell.

Those who support the physical view of secretion—that it is only a separation of a pre-existing material from the blood—adduce the instances of vicarious secretion, as when milk was thrown off from the hands. But such cases do not prove that the secretion really pre-existed in the blood, but only that, after having been originally formed in its own appropriate organ, and being unable to escape, it was taken up into the circulation, and then was poured out from another part, simply as an exhalation. In relation to the secretion of milk, it has been lately asserted that caseine has been detected in the serum of a nursing female. The spermatic fluid most certainly does not exist in the blood, but is formed exclusively in the nucleated cells of the testis. This is well shown in animals during the rutting season, in which the spermatic cells, previously flaccid and empty, now fill up, first with granules, and then with bundles of spermatozoa. In the inferior animals we find examples of secretions which never exist in their blood, for instance, the venom of the serpent; if a drop

of this poison be inoculated into the animal's blood it will prove fatal. Musk and castor are also peculiar animal secretions, but are never found in their blood. In vegetables, the process of secretion is equally simple. All the non-azotized products are formed out of the carbonic acid of the air by the action of cells, through a simple substitution of hydrogen for oxygen; in this manner, the vegetable oils, gums, and resins are produced.

THE LIVER—SECRETION OF BILE.—The liver is probably more universally present throughout the animal scale than any other gland, although its structure is exceedingly variable. Its development is always in the inverse ratio of the respiratory apparatus; hence it is very large in the mollusca and crustacea, while in the insecta it is much smaller, and of a more simple type. The same rule holds true of the human liver during fœtal life, when the lungs are inactive, and the whole function of decarbonizing the blood falls upon that organ.

Minute Anatomy of the Liver.—In the higher vertebrata the liver is made up of a great number of minute lobules, about the size of a millet-seed. Each lobule contains all the component elements of the entire organ, as branches of the hepatic artery, of the hepatic vein, of the vena portæ, of the hepatic ducts, and the secreting cells. The lobules are connected together by areolar tissue and anastomoses of the blood-vessels. The hepatic arterial branches are distributed upon the walls of the hepatic ducts, and form the vasa vasorum of the hepatic and portal veins; they supply the nutrition of the liver. The vena portæ is formed from the collection of the veins of the chylopoietic viscera; then it subdivides like an artery, its branches proceeding to the external surface of the lobules; they are named the *inter-lobular plexus.* The vena portæ furnishes the chief materials for the *bile.* The hepatic vein commences in the centre of each lobule (hence called *intra-lobular plexus*), anastomoses with the inter-lobular plexus, and thus carries off the blood from the vena portæ. The ultimate ramifications of the hepatic artery are believed to discharge into capillaries of the vena portæ; hence its blood, after having become venous, contributes to form the bile. (Kiernan.) The hepatic

ducts form a plexus around the lobules; their relation to the true cells of the liver is not exactly known. The parenchyma of the liver is composed almost entirely of cells. The liver-cells are flattened and spheroidal;—they are arranged in piles, each containing a nucleus, and are filled with bilious matter and fat globules;—their *diameter* is from 1-800th to 1-1600th of an inch. The mode in which bile is separated by these cells, and discharged into the hepatic ducts, is by the usual mode of cell-growth, already described.

The progress of the bile is either directly into the intestine, or it regurgitates through the cystic duct into the gall-bladder, which is its reservoir. It is probable that it is always being secreted,—but its flow into the intestine is determined by the process of digestion; hence, when death occurs from starvation, the gall-bladder is found turgid. In the gall-bladder the bile undergoes concentration by evaporation of its watery particles; and it is mixed also with mucus.

Analysis of Bile.—It is a viscid fluid, of a greenish-yellow colour, and a bitter taste, with an alkaline reaction; it is miscible with water in all proportions. Its solid matter is estimated at 8 to 10 per cent.; of this about one-tenth consists of earthy salts, the remaining nine-tenths being composed of organic matter, which is remarkable for containing a very large amount of carbon and hydrogen, with a small quantity of oxygen and nitrogen. This organic matter is composed essentially of three parts,—the colouring matter, a peculiar resinous constituent, and a small portion of cholesterine or bile-fat,—a crystalline body resembling spermaceti, already described among the fats.

The *colouring principle*—named *biliphæine* by Simon, and *cholepyrrhine* by Berzelius—exists in very small quantities in health, but notably increases in disease, so as to impart a yellow tinge to the solids and fluids of the body, as is witnessed in the colour of the skin, urine, and serum of the blood in jaundice and bilious fevers. It contains 68 per cent. of carbon, 17·9 of oxygen, 7·5 of hydrogen, and 6·7 of nitrogen. From the large amount of carbon which it contains, it has been supposed to be one of the

natural emunctories for the elimination of that substance from the system. Biliphæine is in fact the principal excretory portion of the bile; its other constituents being mostly taken up again into the system. It appears, associated with mucus and cholesterine, to form the chief part of the concretions sometimes met with in the gall-bladder. Its best test is nitric acid, which produces with it a succession of tints of green, blue, violet, red, and yellow.

The origin of biliphæine is ascribed by Simon and Mulder to the metamorphosis of the hæmatine of the blood-corpuscles; and, as a supposed confirmation of this view, we are referred to the successive changes of colour exhibited in an ecchymosed wound; though, in the latter, the play of colours is in the reverse order of those produced by nitric acid on biliphæine.

The urine-colouring matter is named by Simon *hæmaphæine*, and is by him regarded as also a degeneration of hæmatine. The depth of colour of the urine would consequently be an indication of the amount of this disintegration; hence, in this manner, the kidneys may depurate the blood of much carbon.

The *peculiar resinoid principle* of bile has received different names; it is termed *biline* by Berzelius, and, as obtained by him, is a white, shiny, crystalline powder. According to Scherer's recent analysis, it is composed of cholaric acid, glycocoll, and taurine. By Lehmann it is considered as a compound of the taurocholate and glycocholate of soda; the former salt containing six per cent. of sulphur. Biline may be detected in the blood and urine. It is best recognised by Pettenkoffer's test, which consists of first decolorizing the bile, then adding very gradually, so as to prevent a rise of temperature, two-thirds its volume of sulphuric acid, and next a little syrup, and shaking the mixture: a deep, reddish-violet hue is produced. The colouring-matter of the bile alone exists in the fæces in the healthy state, the true bile (biline) passes back into the blood; but in diarrhœa, and under the effects of mercury, biline has been detected in the fæces.

Destination of the Bile.—Much of it is excrementitious, passing off with the fæces;—this portion includes the colouring matter.

As shown by Bernard, it has the property of preventing putrefaction and fermentation in the chymous mass; but its chief use in the digestive process appears to be, when mixed with the pancreatic juice, in the duodenum, to constitute the solvent for the undigested portion of the food which has passed through the stomach, (*vide* Digestion.) It may also perform another function, as before stated,—the transformation of sugar into fatty matter. The use of bile in digestion is shown by an experiment of Schwann: on tying the gall-duct, the animal gradually emaciated and died.

The great design of the liver is to remove from the system the excess of hydro-carbon, which is introduced into the blood chiefly in the non-azotized food. Hence, if more of such food is taken than can be consumed in respiration, or deposited as fat, the office of removing it must devolve upon the liver; if there is too much for this organ, the injurious materials accumulate in the blood, constituting *bilious* diseases. This is especially apt to occur in warm climates, both on account of the nature of the food, and the diminished respiratory action. The remedy is exercise and an avoidance of excess in eating.—The liver is far larger in the fœtus than in the child after birth. In the former state, it is the only decarbonizing agent,—as the lungs do not act.

The Kidney — Secretion of Urine. — The kidneys are purely organs of *excretion;* their function being to remove from the blood certain effete matters, the results of the disintegration of tissues, whose retention would prove a source of positive injury. As the object of the liver is to carry off the excess of carbon from the system, so the part assigned to the kidneys is to remove the excess of nitrogen. They exist in the lowest order of animals, but only as rudimentary organs. They begin to assume importance in fishes, and in the higher reptiles commence to be distinguished by a cortical and medullary substance; they are lobulated in birds.

Anatomical Structure.—The kidney is divided into two well-marked portions, the cortical or vascular, and the medullary. In the former, the *tubuli uriniferi* are very convoluted, and closely interlaced with blood-vessels; in the latter, these tubes are

straight, decrease in number, and converge towards the pelvis of the kidney. The secretion of urine takes places solely in the cortical portion, and is effected by the epithelium-cells lining the tubuli uriniferi, from the vascular plexus on the exterior of the tubuli;—they absorb by endosmose, swell up, burst, and discharge into the tubuli. The *Malpighian bodies* are small dots seen on the cortical portion when cut. Examined by the microscope, they are found to consist of little tufts of vessels. Each of these bodies is supplied by a branch of the renal artery called *afferent*,—which, after forming the plexus, emerges as a single *efferent* trunk, and discharges into the capillary plexus. The solid matter of the urine is secreted by the cells from the capillary plexus, but the Malpighian bodies serve as a strainer, to allow the watery parts to filter through directly into the tubuli. The object of this arrangement is to provide for the constant escape of the watery part of the urine, since this constantly varies, and bears no definite proportion to the solid matter, which is governed by the previous waste of the tissues. Hence, the object of the kidneys is twofold:—to remove from the blood certain solid effete matter, and at the same time to act as a regulating valve, by which the proper amount of water is kept in the system. The amount of water discharged by the kidneys is dependent upon the action of the skin,—the one antagonizing the other.

The whole quantity of urine voided in 24 hours, in health, is differently stated by different authors. Haller estimates it at 49 ounces; Simon at 45; Bostock and Rye at 40; Venables at 40 to 45; Becquerel between 28 and 53; Prout between 30 and 40; the last estimate is the one generally adopted.

As the kidneys are the chief agents for removing from the system the effete matters arising from the disintegration of the azotized tissues, the urine must consequently contain, in solution, numerous solid ingredients arising from this source, besides others, which are thought to be derived from the decomposition of the azotized elements of the food when badly digested, and also, according to Simon, from the disintegration of the blood-corpuscles. A tolerably correct estimate of the aggregate quantity of the

solids of the urine may be made by ascertaining the specific gravity of the urine, which, according to Dr. Prout, in the healthy state, is, on an average, 1·020; Simon gives it at 1·012. The specific gravity, however, differs according to the period of day at which the urine is voided; thus, in the *urina sanguinis*, or that voided early in the morning, the density varies from 1·015 to 1·025; in the *urina potiis*, or that passed soon after drinking, the density is generally very low, sometimes scarcely greater than that of water; in the *urina chyli*, or urine of food, the specific gravity is considerably higher, ranging between 1·020 and 1·030. In estimating the relative amount of solids in the urine, it is also necessary to ascertain the quantity of its watery portion, since a great excess of this would have the effect of lowering the density, although there might be an actual excess of solid matters passed off in the twenty-four hours. Another point of consequence is to attend to the temperature at the time of making the investigation.

Analysis of Urine.—According to Berzelius, there exist in 1000 parts of healthy urine, 933 of water, and 67 of solid ingredients; of the latter, 30·10 represent urea and uric acid, 17·14 organic matters (lactic acid, lactate of ammonia, colouring matters), 18·41 alkaline and earthy salts (sulphates of potassa and soda, phosphates of soda, ammonia, lime, and magnesia, muriates of soda and ammonia, and a trace of fluate of lime). This estimate of the solid ingredients is now generally considered too high; Christison estimates them at about 47 parts in 1000, of which 20 are urea; Becquerel and Prout at 33, of which 14 are urea. The total amount of solids passed in the urine in twenty-four hours, as given by Christison, is 713·561 grains. Becquerel's estimate is 505 grains. From these differences it would appear that the proportion of solids is liable to great variation.

The most important solid constituent of the urine is *urea*, especially in its connexion with pathology. It occurs in colourless prismatic crystals, and is neither acid nor alkaline in its properties; it combines with acids, especially nitric and oxalic, but without neutralizing them; it is very soluble in water, less so in alcohol.

Its composition is $C_2H_4N_2O_2$; and 100 parts contain 20 of carbon, 6·7 of hydrogen, 46·7 of nitrogen, and 26·5 of oxygen.

The whole amount of urea voided in twenty-four hours is liable to great variations, dependent upon age, sex, diet, and exercise; it is stated by Becquerel to vary between 231·570 grains and 277·884 grains; Christison makes it amount to 304·550 grains; and Lecanu found the proportion to be much greater than this; according to the latter, in healthy adult men the minimum quantity was 357 grains, maximum 510 grains, average 433·5; in adult women the minimum was 154, maximum 437, average 295; in old men (84 to 86 years), the average was 125 grains, or only about one-third that of adults, corresponding with the slower waste of their tissues; in children eight years old, the average was 208 grains, or about one-half that of adults; at four years the average was 69 grains; and in children at the breast, none was found.

M. Lehmann's experiments upon himself conclusively exhibit the effect of different kinds of diet upon the quantity of urea; a non-azotized diet yielded 237·9 grains in twenty-four hours; a vegetable diet gave 347 grains; an animal diet, 821 grains; a mixed diet, 501·7 grains. Exercise increases its amount by causing a more rapid waste of the muscular tissues. Alcoholic drinks diminish it.

Urea cannot be considered as a product of the kidneys; they merely separate it, already formed, from the blood. It has been discovered in the blood, though its detection is difficult, as the kidneys remove it as rapidly as it is formed. Its accumulation in the blood would give rise to serious disturbances to the system; it appears to act as a poison, more especially upon the nervous system, producing convulsions or coma, as occurs in certain renal disorders. Prevost and Dumas found urea in considerable quantities in the blood of a dog, after extirpating the kidneys; the same thing occurs in disease where the secretory action of the kidneys is suspended, as observed in some of the severer forms of fever, in albuminuria, and in Asiatic cholera, in which all the secretions are arrested. It may generally be suspected to exist

in excess in the urine, when the specific gravity of the latter is above 1·030. (Prout.)

The best test for urea is nitric acid, which produces no crystallization if urea be not present *in excess*; if there be an excess of it, a brownish-yellow nitrate of urea is formed.

The origin of urea, as already stated, is clearly traceable to the decomposition of the azotized tissues, although there is a diversity of opinion in relation to the *particular* tissue involved. Many physiologists ascribe it to the waste of the proteine tissues, especially the muscular; Prout refers it to the gelatinous tissues; Liebig supposes that the direct product of the disintegration of muscular tissue is uric acid, which is split up, by the oxygen introduced in respiration, into two equivalents of urea, and six of carbonic acid; or, into two of urea and three of oxalic acid,—alloxan being formed intermediately; Dumas supposes it to be derived from the oxidation of the azotized materials of the blood; Simon believes that both urea and uric acid result from the degeneration of the blood-corpuscles, and sustains his opinion on the ground of urea being always found in the urine, even when no azotized food had been employed.

The condition in which urea exists in the urine is supposed by some to be partly in combination with lactic acid; by the best authorities, however, it is believed to be in the free state. It is one of the few organic compounds which can be prepared artificially by the chemist,—by digesting ferrocyanide of potassium with sulphuric acid and the peroxide of manganese (one pound of the ferrocyanide yields three-quarters of a pound of urea.—Liebig). Its formula, $C_2O_2H_4N_2$, is the same as that of the hydrated cyanate of ammonia. By the addition of two atoms of water to urea (or, $C_2O_4H_6N_2$) we have two atoms of carbonate of ammonia (or, $2NH_3\,2CO_2$). Now, this conversion of urea into carbonate of ammonia very readily occurs in the urine after being voided, especially in hot weather, through the action of the oxygen of the air upon some of the nitrogenous principles, causing a species of fermentation. The presence of mucus in the urine facilitates this change; and it takes place under certain conditions in the blad-

der, causing great irritation of that organ. The presence of carbonate of ammonia may easily be detected by the effervescence produced by acids. The urine in health is always slightly acid; but it becomes alkaline in disease, in the manner just mentioned, and this causes a precipitation of the phosphates. In some cases, however, the urine is alkaline *before* it has passed into the bladder, having been secreted in that condition. Moreover, in certain forms of mental derangement, as melancholia and mania, the urine is very prone to assume the alkaline condition.

A deficiency of urea occurs in certain obscure chronic cases where there is a very slow metamorphosis of the tissues. Its excess in the urine will produce very frequent and uncontrollable desire to urinate.

Uric or *Lithic Acid* is another important principle in the urine, in which it exists, combined with ammonia, or soda. Its proportion in healthy urine is very small,—one part in 1000, according to Berzelius; 0·65, according to Christison; and 0·5, according to Becquerel. In the urine of the lower vertebrata, as serpents, it constitutes a large portion of the solid matter. The quantity excreted in twenty-four hours, as given by the different authorities, is from eight to ten grains; but this varies, as in the case of urea, according to the age, sex, diet, and exercise of the individual: thus, Lecanu states the average to be, in adult men, 13·153 grains; in adult women, 10·034 grains; in old men, 6·792 grains; in young children, 1·775 grains. A similar variation is produced by diet. In the same person, in a given time, but little change in the quantity of uric acid is produced. It also increases when the perspiration is checked; also in fever, rheumatism, gout, and some other disorders. The urine of serpents and birds consists almost exclusively of uric acid, and urates.

When pure, uric acid is in the form of minute, white, shining crystals, without odour or taste, very nearly insoluble in water, and soluble in nitric acid. The best test for its presence is to evaporate the nitric-acid solution to dryness, and add a few drops of solution of ammonia: a deep purple hue will be produced,—the *murexide* of Liebig, or *purpurine* of Bird. Its composition, ac-

cording to Liebig, is, in 100 parts, 36 carbon, 24 hydrogen, 33·3 nitrogen, 28 oxygen; its formula is $C_{10}N_4H_4O_6$.

When uric acid exists in the urine in excess, it is deposited as the urine cools, either in the form of crystals, constituting red and yellow gravel, or combined with ammonia in the form of an amorphous sediment, of a whitish, yellow, pink, or purplish colour, according as it is mixed with the various colouring matters; the latter occur as the *lateritious deposits*, which are so characteristic of fevers and inflammations. When they float through the urine, so as to give it a turbid appearance, it is a sign of the continuance of the inflammation, but if they subside, leaving the fluid clear above, it indicates a favourable crisis. If the crystalline deposits are perfectly white, they are most probably *phosphates*, and are the results of nervous disorder. Sometimes the urates are deposited in the pelvis of the kidney in large masses, which, on their passage along the ureters, occasion excessive pain, and not unfrequently lay the foundation for calculus.

In gout and rheumatism, the excess of uric acid is usually found in combination with soda, which is sometimes produced in such abundance as to be thrown out around, and within the joints, constituting the *chalk-stones* of gouty persons.

On referring to the composition of urea and uric acid, it will be observed that they contain a very large amount of nitrogen. The quantity of urea voided in twenty-four hours indicates that 800 grains of muscular tissue are disintegrated in that space of time; and 15 grains by the uric acid,—the two combined being equivalent to nearly *two ounces* of azotized tissue; an additional quantity of nitrogen is also eliminated in the ammonia of the cutaneous exhalation.

Another constituent of the urine is *hippuric acid*,—so named from existing in large quantities in the urine of the horse. It was formerly supposed to be peculiar to the urine of herbivorous animals; Liebig has shown it to be a natural ingredient also in human urine. It is easily procured by evaporating the fresh urine of the horse, cow, &c., and acidulating with hydrochloric acid; on standing, the liquid deposits brown crystals of hippuric acid, which

may be decolorized by bleaching liquid and hydrochloric acid. It is in the form of long, four-sided prisms, of a bitter taste, soluble in 400 parts of cold water, more so in boiling water, and still more soluble in alcohol, by which it may be separated from uric acid. It is transformed into benzoic acid during the decomposition of the urine. Nitric acid converts it into the benzoic; and sulphuric acid, by the addition of heat, into benzoic and carbonic acids, and ammonia. It forms salts with the bases, most of which are soluble and crystalline. Its composition is, in 100 parts, 60·7 carbon, 5 hydrogen, 8 nitrogen, 26 oxygen;—formula, $C_{18}H_8NO_5+HO$. From the large amount of carbon which it contains, Dr. G. Bird regards it as one of the means by which this element is separated from the economy.

According to Liebig, hippuric acid is derived from the non-azotized elements of the food. It may be viewed in two ways: first, as a compound of benzamide with an acid, C_4HO_3 (fulmaric or aconitic acid?); secondly, as composed of hydruret of benzule, hydrocyanic acid, and formic acid. Either view readily accounts for its ready decomposition into benzoic acid and other compounds. Dr. Ure was in error in supposing that benzoic acid, when taken into the system, had the power of converting uric acid into hippuric; the fact being that benzoic acid is itself very soon transformed into hippuric acid, and, as such, appearing in the urine.

It has long been known as an empirical fact, that the solid constituents of the urine were increased in the crisis of fevers, constituting the lateritious deposits. Dr. Golding Bird ascertained that in the commencement of a paroxysm of intermittent fever, the solids of the urine diminished to 352 grains; but that in the declining stage they augmented to 1054 grains. He further ascertained that the constitution of the urine is very much under the control of medicinal agents, the watery portion alone being in some cases increased, as in certain nervous disorders, particularly hysteria; while the increase of the solids occurs only in acute cases, especially miasmatic fevers and inflammations. Dr. Bird found that the majority of the diuretics acted simply by eliminating the watery elements of the blood, and to these he has applied the

term of *renal hydragogues;* there are others, however, which really depurate the blood, carrying out the solid matters from the system, and materially augmenting the solid constituents of the urine; these comprise the alkaline salts, especially the acetate and nitrate of potassa, the carbonates of potassa and soda, and the iodide of potassium, and are very appropriately named *renal depurants.* These last-mentioned diuretics are known to have the power of acting chemically upon albumen and other proteine elements, out of the body; it is thus, in all probability, that they produce an alterative effect when taken as remedies, breaking down the morbid structure, which is always most apt to give way under such circumstances. The hydragogue diuretics comprise the vegetable medicines of this class, as squill, juniper, digitalis, colchicum, &c., which are so useful in dropsies. In proof of the correctness of his views, Dr. Bird cites a case of a female affected with dysuria, whose urine he could very accurately examine; this patient passed sixteen ounces of urine a day without using any medicine, and forty-six ounces in the same time while taking the acetate of potassa; the solid constituents were increased, by the employment of the latter remedy, from 416 grains to 782 grains; the urea from 130 to 202 grains; the uric acid from 1·5, to 3·5 in 1000 parts; the soluble salts from 72 to 248 grains in a day (but some of the last was due to the alkali administered); the insoluble salts from 21 to 32 grains; the extractive from 189 to 295 grains. Now, allowing for the increase of the soluble salts due to the remedy given, there was here an actual gain of 190 grains of solid materials in twenty-four hours, due solely to the influence of the diuretic.

Viewed in the above light, the kidneys hold a most important rank in the animal economy, especially in connexion with pathology.

Uric or *Xanthic Oxide* occurs only as a very rare form of urinary calculus, from which it may be obtained in a separate state. Its formula is $C_5H_2N_2O_2$.

Cystic Oxide or *Cystine* is another very rare principle of the urine; it likewise occurs only in calculous deposits. Dr. Davy

discovered it in the urine of the spider. It is chiefly remarkable for containing a large amount of sulphur. Its composition is $C_6H_6NO_4+S_2$.

Kreatine, Kreatinine, and Inosinic Acid.—These three substances have been lately discovered by Liebig in the juice of muscular flesh, which was long since known to contain an acid—supposed by Berzelius to be lactic acid. It is now ascertained that this juice contains the above-named principles, together with lactic acid, salts of the alkaline phosphates, and salts of potassa.

Kreatine and kreatinine have been found in minute quantities in human urine. Kreatine exists in the flesh of all animals, though in very different proportions. According to Liebig (*Chemistry of Food*), the flesh of fowls and the marten contains it in greatest quantity; next in order, the flesh of the horse, fox, deer, hare, ox; and least, in fishes. It is more abundant in wild animals, and in lean flesh. The heart contains more of it than any other muscle. When pure, kreatine is in the form of transparent, colourless crystals, soluble in boiling water, but not in alcohol. It is a neutral body, combining with neither acids nor bases. Formula, $C_8H_9N_3O_4+2HO$.

Kreatinine is procured from kreatine, by the action of strong acids, with the separation of four atoms of water. In the natural state it is probably derived from kreatine by a process of degeneration. It is in the form of colourless prismatic crystals, more soluble in water than kreatine, and strongly alkaline in its reaction. It is also soluble in alcohol. Formula, $C_8H_7N_3O_2$.

Inosinic Acid is contained in the mother liquor of muscular flesh after the removal of kreatine. It does not occur in the urine. It has strong acid properties. Composition, $C_{10}H_6N_2O_{10}+HO$.

Sarcosine is the term given to a new peculiar substance obtained by treating kreatine with caustic potassa.

Liebig ascribes the nutritive properties of muscular flesh to kreatine and kreatinine, supposing that these principles exist in it as true educts. Another opinion generally adopted is that they are both the results of the disintegration of the muscles, since both are found in the urine. It is not improbable also that they

may be produced by the decomposition of the glycocoll of the gelatinous tissues, as well as from the fibrinous: thus 2 equivalents of glycocoll, $C_8H_8N_2O_6$, and 1 equivalent of ammonia, NH_3, would yield 1 equivalent of kreatine, $C_8H_{11}N_3O_6$. If they be regarded as the result of muscular degeneration, they are probably the intermediate link between proteine and urea.

Kiesteine.—This is a peculiar azotized principle discovered in the urine of pregnant women. It is not observed until three or four days after the urine is voided, when it forms a greasy pellicle upon the surface. Examined by the microscope, this is found to be due to fatty globules, resembling milk-globules. It was at one time considered as a certain sign of pregnancy; but it is sometimes absent, and it occurs in the urine of nursing women, whose milk is deficient; and even in some instances, in the urine of men. It appears to be a modification of caseine.

The kiesteinic pellicle may be distinguished from that produced by the phosphatic deposits, by the circumstance of the latter occurring very soon after the urine has cooled; the former requires some days for its formation, and after remaining for two or three days, it breaks up and falls to the bottom of the vessel.

Lactic acid is also generally considered one of the organic constituents of urine; but this is denied by Liebig. Prout considers the presence of lactic acid to be the chief cause of the precipitation of uric acid, particularly when connected with indigestion.

The *saline matter* of the urine consists chiefly of sulphates of soda and potash, muriates of soda and ammonia, and phosphates of soda and ammonia. The excess of the phosphates is believed to be due to the waste of the *nervous* tissue. As before mentioned, there is a correspondence between the presence of phosphatic deposits in the urine, and excessive mental labour.—The treatment of urinary deposits should be based upon a proper knowledge of the constituents of the urine. The consequence of a total *suppression* of urine is death,—chiefly from accumulation of urea in the blood: even partial retention is very serious; it operates chiefly upon the brain and nervous system, exerting a depressing poisonous influence upon them.

Besides the above-mentioned ordinary constituents of the urine, it frequently contains substances which have passed into it unchanged, from the food or drink. The rapidity with which such matters often pass into the urine has been lately explained by M. Bernard, who has demonstrated the existence of a direct communication between the vena portæ and the inferior vena cava, distinct from the ordinary route; the vessels are situated below the hepatic veins, at the point where the substance of the liver adheres to the inferior cava. They are particularly conspicuous in the horse. During digestion, when the portal system becomes congested with blood, a portion of it passes off by this diverticulum at once into the vena cava; and instead of progressing on to the right side of the heart, it is forced to take a downward course into the *renal veins* by the contraction of a set of longitudinal muscular fibres (claimed by Bernard to have been discovered by him, in the walls of the vena cava, and the hepatic veins). In this manner it is that many substances, during digestion, pass into the portal system, and then directly into the kidney, without having gone the round of the circulation. In this way is explained the frequent innocuousness of poisonous substances administered during digestion. Hence it would appear that the renal veins, during digestion, act as arteries, just as the pulmonary veins do for the lungs, or the portal vein for the liver.

The Mammary Gland—Secretion of Milk.—The secretion of milk is peculiar to females of the class *mammalia;* and it is one of those which are destined for special uses in the economy. The mammary glands are found in both sexes, and present no striking difference in them till about the period of puberty. In the female they attain their full size, previous to lactation, about the age of twenty. During pregnancy they become more vascular, and at parturition their lobulated character is distinguished; but the milk-follicles cannot be injected till full lactation. The *areola* is much developed during pregnancy. The mammary gland of the male is a miniature representation of that of the female. It does not undergo development, except under very rare circumstances. One or two instances, however, are on record of men performing

the office of wet nurse. In the case recorded by Dr. Dunglison, the secretion was induced by the individual applying the children entrusted to his care to the breasts, during the night.

Minute Anatomy.—The mammary gland consists of a number of glandulæ or lobules, held together by areolar and fibrous tissue. The lobules are composed of a number of minute follicles, from which excretory ducts arise; these converge, and unite so as to form ten or twelve lactiferous tubes, which open about the centre of the nipple. At the base of the nipple these tubes dilate into reservoirs intended to hold a supply of milk;—these are larger in the lower animals than in the human female. The secretion of milk occurs in the follicles, from their epithelium-cells, which absorb the materials from the surrounding blood.

Composition of Milk.—Milk consists of water, containing caseine, sugar, salts, and oil-globules (*milk-globules* of Donné). The oil-globules rise to the surface when the milk is allowed to remain at rest, constituting *cream*,—which also includes some of the caseine, sugar, and salts. These may be mostly separated by the process of churning, which ruptures the envelopes of the oil-globules, constituting *butter* from their aggregation, and *buttermilk* containing the caseine, sugar, and salts; butter yet contains some caseine, which can be separated by a temperature of 180°. After removal of the cream, the milk still contains most of the caseine and sugar; spontaneous change occurs in this, by conversion of the sugar into lactic acid, which precipitates the caseine in flakes: this precipitation may be occasioned at any time by an acid, but especially by *rennet*, or the dried stomach of a calf, which is so powerful that it will coagulate the caseine of 1800 times its weight of milk. The *whey*, which is thus left, contains a great portion of the sugar and saline matters, which may be separated by evaporation.

The oleaginous matter consists of *oleine* and *stearine*, together with a peculiar fatty substance termed *butyrine*. To the latter the peculiar smell and taste of butter are due; it is converted by saponification, into three volatile odorous acids—the *butyric*, *caproic*, and *capric* acids.

The caseine is distinguished from albumen, by not being coagu-

lated by heat alone, and by its being precipitated by feeble organic acids, as lactic. It is retained in solution, in milk, by the presence of an alkali.

The saline elements resemble those of the blood; they consist of the phosphates of soda, magnesia, and lime, the chlorides of potassium and sodium, free soda in combination with the caseine, and a trace of iron. The phosphate of lime in considerable quantities is held in solution by the soluble caseine, just as it is in the blood by the soluble albumen. By incineration, several lactates are yielded, the result of previous changes. The saccharine principle, named *lactine* or *sugar of milk*, has already been treated of. (Part II.) The milk of the carnivora contains no sugar.

Milk is the only secretion which contains, to any degree, the three classes of principles required for human food—viz., the albuminous, oleaginous, and saccharine.

The proportions of the above constituents of milk vary considerably in different animals, and at different times. Human milk contains, in 1000 parts, 29 parts of oily matter, 32 of caseine, and 36 of sugar; cows' milk contains, in the same quantity, 40 of oily matter, 63 of caseine, and 28 of sugar; goats' milk yields 40 of oily matter, 80 of caseine, and 40 of sugar; asses' milk yields 12 of oily matter, 19 of caseine, and 62 of sugar. By a comparison of the milk of the cow and that of the human female, it will be seen that the former exceeds the latter in caseine and oily matter, but is deficient in sugar; hence, when it is employed as a diet for infants it should be diluted one half with water (or preferably, with barley-water), and sweetened; sometimes a little cream may be added with advantage.

Good milk should yield from 9 to 13 per cent. of cream in twenty-four hours, and should not exhibit a bluish appearance.

The quantity of sugar and butter in the milk is chiefly influenced by the amount of these substances in the food,—also, by the amount of them consumed in respiration; thus, a low temperature and much exercise, by increasing respiration, eliminate much of the oily and saccharine matter, in the form of carbonic acid and water; whilst rest and warmth, by diminishing this

drain, favour their passage into the milk. On the other hand, the proportion of caseine is increased by *exercise;* which would seem to show that the caseine was derived from the disintegration of the tissues. To illustrate this:—cattle pastured in exposed situations, as in Switzerland, where they have to use much exercise, yield but a small amount of butter, but a large proportion of cheese; but when they are stall-fed, they give a large quantity of butter, and very little cheese.

The term *colostrum* is applied to the milk first secreted after parturition: it differs from common milk in being purgative,—a quality which is useful for removing the *meconium* from the bowels of infants. This depends upon the presence of certain large, yellow, granulated corpuscles, as seen by the microscope, differing from the true milk-globules in the fact that the cell-wall is composed of albumen instead of caseine. If this condition of the milk continues too long, it proves injurious to the child.

The influence of the nervous system upon the secretion of milk appears to be greater than in other secretions; it is seen in the effects produced upon the secretion by violent emotions and passions, as terror, grief, rage, &c.; convulsions have been thus produced in sucking children; hence the propriety of attending to the temper and disposition of a nurse. The milk may also be affected by the constitution of the nurse, as from chronic diseases; this is especially the case in large cities, where, very frequently, the milk of the mother is found to be innutritious to the child. In the same way, also, disease may be communicated to a child at the breast, as witnessed in the case of syphilis, &c. Diseased milk is usually found to be deficient in caseine and sugar, but abundant in water and salts. Finally, the milk of a nurse may be rendered medicinal through absorption of medicines into the blood.

The quantity of milk secreted by a nurse cannot readily be ascertained, since most of it occurs at the time of suckling. The largest breasts do not always secrete the most milk, since their size is often owing to the presence of much adipose matter.

The Salivary Glands and Pancreas.—The salivary glands consist of three pairs:—the *parotids, sub-linguals,* and *sub-maxillaries.* Their structure is very similar to that of the mammary gland, —being composed of minute follicles containing the true secreting cells, which separate the saliva from the surrounding capillary plexus, by the usual process of cell-growth. The follicles discharge into an excretory duct. The quantity of saliva is not constant; its *flow* takes place when most wanted, that is during mastication; it occurs also in a hungry person, as an emotion. The quantity secreted in twenty-four hours is estimated at fifteen to twenty ounces. As obtained from the mouth it is mixed with mucus and epithelial scales. If the amount of mucus be considerable, the saliva has an acid reaction; if not, the reaction is alkaline.

Composition.—The solid matter amounts to one per cent.; of this, the animal matter consists of osmazome, mucus, and a peculiar matter called *ptyaline,* which is soluble in water, and insoluble in alcohol, but yet is not identical with albumen. Ptyaline seems to act as a ferment, since by it starch may be converted into sugar, and sugar into lactic acid. It has previously been noticed (Part II.) The *saline constituents* of saliva are nearly the same as those of the blood; its alkaline reaction is due to the tribasic phosphate of soda. The *tartar* of the teeth is owing to the earthy phosphates of the saliva, which are held together by about twenty per cent. of animal matter. The composition of the *salivary concretions* is similar. The alkalinity of the saliva is asserted to bear a direct proportion to the acidity of the gastric juice.

The *Pancreas* resembles in its structure the true salivary glands, being composed of aggregated follicles; its secretion appears to be essentially the same as the saliva. Its influence, together with that of the saliva, upon digestion is fully noticed under Digestion.

The Lachrymal Gland—The Tears.—Its composition is very similar to that of the parotid, consisting of lobules, whose ultimate structure is of follicles lined by cells. The *tears* very much resemble the serum of the blood deprived of its albumen;

their action is slightly alkaline. They are useful to lubricate the eyes,—the excess being absorbed into the nasal duct, chiefly by capillary attraction. This secretion is very much influenced by the emotions and passions, through the nervous system.

The Testis—Spermatic Fluid.—The anatomical structure of the testis resembles that of the kidney. It is composed of a number of lobules, each containing a mass of *tubuli seminiferi*, through which the blood-vessels are distributed. The lobules vary in size,—some containing more tubuli than others. The convolutions of the tubuli are so arranged that the lobules form a cone, whose apex is presented towards the rete testis. The diameter of the tubuli is very uniform, from the 1-95th to 1-170th of an inch. The tubuli cease to be convoluted before entering the rete testis, where they are named *vasa recta*. The *rete testis* consists of from seven to thirteen vessels running in a waving direction; they then become *vasa efferentia*, and go to form the *globus major* of the epididymis. The *epididymis* is a very convoluted canal, about twenty-one feet in length; its lower extremity is named *globus minor*, and terminates in the excretory duct, or *vas deferens*.

The original formation of the testes, in the embryo, is from the *corpora Wolffiana*—alongside of the kidneys. In the human embryo, they first appear about the seventh week. They begin to descend about the middle period of gestation, and usually reach the scrotum at the ninth month.

The *spermatic fluid* is thick and tenacious, of a grayish-yellow colour. It is difficult precisely to determine its character, on account of its being mixed with the secretion of the prostate gland, and of the mucous lining of the vesiculæ seminales and spermatic ducts, before it is emitted. It has an alkaline reaction; it contains albumen and a peculiar animal principle named *spermatine;* likewise some salts, chiefly muriates and phosphates. The distinctive character of the semen is due to numerous small bodies found in it alone, and denominated *spermatozoa*. These will be more fully spoken of under the head of Reproduction.

The Cutaneous and Intestinal Secretions.—The skin is the seat of two secretions: the one—the *perspiration*—being ac-

complished by the sudoriparous glands; the other by the sebaceous glands.

The *Sudoriparous* or *Sweat Glands,* consist of the convolutions of a single tube, situated just beneath the cutis; this continues to the surface as the excretory duct, running in a spiral direction, and perforating the epidermis in an oblique or valve-like manner. These glandulæ are exceedingly abundant over the whole body; Mr. E. Wilson says there are three thousand five hundred and twenty-eight of them on a single square inch of surface; he has calculated the *whole length* of the perspiratory tube on the surface of a man of ordinary stature, to be 48,611 yards, or nearly twenty-eight miles. The perspiration is divided into insensible, and sensible, or *sweat.* The former is the more usual; the latter is occasional, and is caused by excessive action of the glandulæ, or by excess of moisture in the atmosphere, preventing the evaporation from the surface. It is difficult to procure it for analysis free from the sebaceous and other matters. It usually has an acid reaction, due to lactic or acetic acid, to which the sour smell is owing. The proportion of solid matter varies from one half, to one and a half per cent., consisting chiefly of an animal matter, along with some saline matters derived from the serum of the blood.

The amount of fluid exhaled from the skin is dependent upon the surrounding temperature; being greater when it is high, and less when it is low, always provided the air be dry. The object of the increase of perspiration when the external heat is great is to keep down the temperature by the *evaporation;* but as this cannot take place, if the atmosphere be already loaded with moisture, a hot moist air proves fatal to life. The cause of the increased secretion is due to the increased quantity of blood sent to the surface under the stimulus of heat. The entire loss of fluid by exhalation, from both the lungs and skin, in twenty-four hours, varies from one and two-thirds, to five pounds. Of this quantity, more than two-thirds are due to the cutaneous exhalation.

The secretion of the kidney is vicarious with the exhalation from the skin and lungs, both as to the fluid and solid materials.

The amount of solid matters daily thrown off by the skin, amounts to about one hundred grains; hence the importance of a due attention to the function of the skin in urinary diseases, as well as others. When the exhalent action of the skin is completely checked, as by the application of an impermeable varnish, the effect is to lower the temperature of the body, from imperfect aeration of the blood, and ultimately to cause death; a partial suppression will cause fever, and albuminuria, or escape of the albumen of the blood into the urinary tubes, in consequence of the increased amount of albumen then sent to the kidneys. Hence, we can understand how certain cutaneous diseases, which affect the whole surface at once, will cause intense febrile symptoms, and sometimes *albuminuria*,—as seen in scarlatina. The perspiration is also greatly influenced by the nervous system; thus it is increased by the depressing emotions—as grief, fear, &c.; but diminished by high nervous excitement.

Nature seems at times to make use of this emunctory to rid the system of some morbific matter, as seen in the critical perspirations occurring in fevers, and in the acid sweats of some forms of rheumatism.

The *Sebaceous Glands* are also found scattered over the skin,—most abundantly about the face and scalp. They differ greatly in size and complexity, some being simple follicles lined by secreting cells, whilst others are more convoluted, and others again, in certain parts of the body, have a *special* function—as the *Meibomian glands* of the eyelids, and the *ceruminous glands* of the ear, which secrete the ear-wax. In the hairy part of the skin, a pair of sebaceous follicles is usually found opening into the passage through which the hair ascends. It is probable that the *odoriferous glands* are of the same nature: they are especially abundant in certain animals, and in certain races and individuals of mankind.

The sebaceous matter is useful to lubricate the skin, and protect it from the sun and air; it is much more abundant in those living in warm climates.

The sebaceous glands are sometimes the seat of a certain para-

site resembling a worm. It is not certain how far the sebaceous secretion is designed to eliminate noxious matters from the blood.

The mucous surface of the alimentary canal, like the skin, is furnished with a great number of glandulæ, varying from a single follicle, to a lobulated mass with an excretory duct. The function of the simple crypts and follicles is to secrete the protective mucus for the surface of the lining membrane.

The *Gastric follicles* of the stomach are arranged in the form of tubes, closely packed together, opening into the bottom of small depressions, or pits, which are more or less circular, their diameter being from 1-100th to 1-250th of an inch. The number of follicles opening into each pit varies from three to five. The function of these follicles is to secrete the gastric juice.

The *follicles of Lieberkühn* are little inflexions of the mucous membrane of the small intestines, whose office is the secretion of mucus. The intestinal follicles become more prolonged in the large intestines, constituting a peculiar layer between the mucous and muscular coats;—their *function* is to secrete the thick tenacious mucus of the part. All these follicles become more evident when the membrane is inflamed;—they then secrete a whitish matter.

Other glandulæ are contained in the intestines, called *Brunner's and Peyer's glands.* The former are found in the duodenum, in the submucous coat. Though only the size of a hemp-seed, they consist of a vast number of follicles, united around a common excretory duct, resembling in structure the salivary glands. *Peyer's glands* are either solitary, or in clusters; the latter form large patches, which are made up of aggregations of the former. Each solitary gland of Peyer consists of a closed vesicle, surrounded by a circle of openings, like Lieberkühn's follicles. Its secretion is discharged directly into the intestine, by a sort of rupture of the vesicle. The membrane which covers the cavity of the glands is very thin, and liable to be destroyed in typhoid fever by ulceration, caused, as is believed, by the deposit there of a peculiar matter, called *typhus matter.*

The function of the glands of Brunner and Peyer is not per-

fectly known, but there is a strong reason for the belief, that it is purely one of *excretion*—to eliminate putrescent matters from the blood, whether resulting from the normal waste of the system, or from morbific causes. No doubt much of the fæcal matter is derived from these glands, for we see it discharged from the bowels when no food whatever has been taken. Hence, the value, often, of a critical diarrhœa to rid the system of morbific matter. The colliquative diarrhœa coming on at the close of exhausting diseases,—the usual precursor of death,—is probably due to the general disintegration of the solids of the body, the decomposing matter of which finds its way into the bowels, by exciting these glands to great activity. We should be careful to avoid exciting the irritable mucous membrane, in typhoid fever, by purgatives.

Of the Spleen, and other similar Glandular bodies.—Although these bodies are not, strictly speaking, to be regarded as true glands, since they possess no excretory duct, still, the present place appears to be as suitable as any other, for their consideration.

The *Spleen* is an organ of compound structure, and has probably two distinct offices to fulfil. It consists of a fibrous envelope, which sends prolongations into the interior, so as to divide it into a great number of minute cavities or cells, which are termed the *splenic follicles.* These follicles communicate freely with each other, and with the splenic vein. The interstices between the follicles are made up of the *parenchyma* of the spleen, which consists of reticulations of blood-vessels and lymphatics, with a large quantity of minute globules or incipient cells, of about half the diameter of blood-corpuscles, which lie in the meshes of the capillary network, and which seem to be intimately connected with the lymphatics. The *Malpighian bodies* of the spleen are a large number of bodies, about the third of a line in diameter, lying in the midst of the parenchyma. These resemble lymphatics in miniature; they contain lymph of an opaque character,—an appearance resulting from the large number of lymph-corpuscles that float in it. The walls of the spleen-cells are very distensible, which accounts for the great size this organ will sometimes attain: thus the spleen of a sheep, which weighs four ounces, may be

made to contain as much as thirty ounces of water; and by tying the portal vein of an animal whose spleen weighs only two ounces, the weight is found to increase to twenty ounces. From this latter circumstance, and from the fact that the spleen becomes very much distended in asphyxia, and in the cold stage of intermittent fever, in which the blood is driven from the surface to the internal organs, the idea is entertained that the spleen serves as a diverticulum or safety-valve to the portal system and lungs. As is well known, the spleen becomes permanently enlarged in chronic ague, constituting the "ague-cake." Again, the spleen seems to act as a reservoir for the superfluous blood during digestion. Its maximum size is attained about five hours after a meal.

But there appears to be another function performed by the spleen, analogous to that of the lymphatic glands. This inference is derived from the strong resemblance between the Malpighian bodies and the lymphatic glands; and is confirmed by the fact, that extirpation of the spleen is soon followed by a great increase in the size of the neighbouring lymphatic glands. This view is also supported by the fact, that while a spleen is always found in animals possessing an absorbent system, it does not exist in those which are destitute of that system.

The *Supra-renal Capsules* resemble both the spleen and kidneys in their general structure; and, like the former, it is supposed they may have a double function,—serving as a diverticulum to the kidneys, and participating in the general absorbent system. The supra-renal capsules are particularly large in early fœtal life,—surpassing the kidneys in size, up to the tenth or twelfth week.

The *Thymus Gland* is another body of much greater importance to fœtal than to subsequent life. It resembles, in all respects, a true gland, save that it has no excretory duct. It consists of a number of follicles containing a fluid in which numerous corpuscles, resembling the white blood-corpuscle, are found. The time of its greatest development is in the early period of extra-uterine life, and not, as has been represented, in the fœtal state. Its *function* would seem to be somehow connected with that of the absorbent glands,—elaborating the nutritive material, which is

conveyed away by the lymphatics. Its increase usually ceases about the age of two years; after which it appears to be converted into a mass of fat, by the development of its corpuscles into fat-cells. It has also been supposed that the thymus gland may act as a diverticulum to the lungs; the fact that it is not to be found in fishes is strongly confirmatory of this idea.

The *Thyroid Gland* resembles the thymus in its general character, but its vesicles are distinct from each other, and do not communicate with a common reservoir. Its arteries and lymphatics are particularly large. Although proportionally larger in the fœtus, it still remains of a considerable size throughout life. From all the researches into the nature of its function, it would appear destined, like the foregoing organs, to serve a double purpose,—acting as a diverticulum from the brain, and aiding in the elaboration of nutritive matter.

CHAPTER III.

PHYSICAL ACTIONS OF THE ORGANISM.

THE *physical actions* of the economy include many important functions, and are very intimately connected with life. They comprise the following: *Capillarity* and *Imbibition*, *Endosmose*, *Absorption*, *Diffusion of Gases*, *Exhalation*, *Elasticity*, and *Electrical Phenomena*.

1. CAPILLARITY and IMBIBITION are modifications of the same molecular attraction; imbibition is nothing more than capillary attraction exhibited in porous bodies, which may be regarded as an assemblage of fine capillary tubes. As all animal tissues are more or less *porous*, they exhibit the phenomena of imbibition. It has already been shown that many of the tissues of the body are dependent for the performance of their functions on their

power of imbibing water: thus, a piece of dried artery is perfectly inelastic, but it recovers its elasticity as soon as it is soaked for a time in water. The same thing is true of the cornea, which when dried is opaque, but recovers its transparency simply by the imbibition of water. All the so-called absorption of liquids from the stomach is nothing more than simple imbibition through its mucous coat into the capillaries below; in this way we can account for the very rapid disappearance of fluids from this organ. In the same way, also, solid matters, perfectly soluble in water, pass from the stomach directly into the circulation. All the mucous membranes possess this property of imbibition; this is especially true of the lining membrane of the lungs, which is known to absorb by imbibition more rapidly than any other part of the body. It likewise occurs from serous membranes.

2. Endosmose and Exosmose.—These physical actions were first noticed by Dutrochet: their literal signification is *a flowing in* and *a flowing out.* At present, the term endosmose is used to designate the stronger current, whatever be its direction. Endosmose is a modification of capillarity and imbibition. Certain conditions are necessary for its display: *first,* there must be two liquids of different densities, separated by a membrane or partition; the current usually sets from the rarer to the denser liquid. *Secondly,* the fluids must have an affinity for each other; thus, between oil and water no endosmose will take place. *Thirdly,* there must be an affinity between the septum and at least one of the liquids; thus, a thin layer of freestone, though exhibiting mere imbibition, does not produce a true endosmotic current between two liquids. The affinity between the liquid and the septum will even sometimes reverse the direction of the current, so as to cause it to flow towards the rarer liquid,—as from water to alcohol, if a septum of bladder be interposed between these two liquids; if the septum be composed of caoutchouc the flow will be reversed, on account of the greater affinity between the membrane and the alcohol. Heat also appears to exercise a disturbing influence upon the endosmotic currents. The intensity of the current is generally proportionate to the density of one of the fluids;

but in certain cases the intensity varies in fluids of the same density. Matteucci ascertained that the intensity of endosmose in solutions of gelatine, gum, sugar, and albumen—all of the same density,—might be expressed by the numbers, 3, 5, 11, and 12. It was farther ascertained by the same experimenter, that a solution of albumen having a density of 1·5, would produce an endosmotic force equal to four and a half atmospheres, or one that would support a column of mercury the height of one hundred and twenty-seven inches.

Endosmose is a property common to all the organic cells. It is well shown in the blood-corpuscles. If these be placed in pure water, an inward current of the latter takes place, and the corpuscles swell up and frequently burst, pouring out their contents. On the other hand, if they are placed in a tolerably thick solution of sugar or gum, they collapse, because the endosmotic flow takes place from their interior. In this way, the quality of the serum of the blood must materially affect the corpuscles.

Certain important functions of organized beings are intimately connected with endosmose. The circulation of plants is chiefly due to it. The roots of plants terminate in a very delicate network of tubules termed *spongioles;* these act as a membrane or septum between the water derived from the soil and the thick descending sap, which has parted with a large part of its water by exhalation. Endosmose consequently takes place in the spongioles; and the ascending sap often flows with very considerable force up to the highest branches of the tree. The force of the ascending sap is well exhibited in the sugar maple, when wounded in the spring; it is also seen in the grape-vine. Hales estimated the endosmotic force in the latter to be equal to that which would sustain a column of mercury several inches. Endosmose also influences, if indeed it be not the true cause of the *capillary circulation.* In the capillary rete the blood is contained in a closed membrane surrounded by a semifluid structure of newly-organized matter. In the process of nutrition, the plasma or fluid portion of the blood exudes through the capillary membrane; this of course must constantly tend to produce a partial vacuum in the

vessels, which would be filled immediately by the blood behind, and in this manner, the capillary circulation would continue.

In like manner, endosmose can be applied to explain the *lymphatic circulation.* The plasma which is effused in the acts of nutrition and organization parts with its solid portions—albumen and fibrine—to the various molecules of the tissues; the liquid portion, consisting chiefly of water, then passes by endosmose into the lymphatics, which already contain a fluid of greater density; and in this way a current of considerable force is produced.

The law of endosmose is influenced by the physiological condition of the membrane. The presence of a small quantity of sulphuretted hydrogen will prevent it. The same thing is stated to occur from the presence of the *wooraara* poison of South America, which may be swallowed with perfect impunity, in consequence of its absorption from the stomach being in some way prevented. The same thing is true of the venom of poisonous serpents. Commencing putrefaction in the membrane will also arrest the endosmotic action. The occult poison supposed to be the cause of cholera would appear, in some unknown way, to influence this action in the alimentary canal; since in this affection there is an escape of the water of the blood into the intestines, and it is impossible to reverse the current by injections, &c., as in ordinary diseases. Poisscuille affirms that the presence of morphia arrests the endosmotic currents in a saline solution.

It would appear that endosmose was endowed with a a *selective* power, receiving certain materials with the fluid, and rejecting others. This is well seen in plants, whose roots absorb along with the water certain inorganic materials, but reject others. The cereals, for example, as wheat, oats, barley, &c., take up the silicious matters from the soil, whilst the leguminosæ select only the calcareous matters. In the animal cell, the same selective power is manifested; and is believed to be more especially the property of the nucleus.

The action of many medicines is partly, at least, due to endosmose. A strong saline solution taken into the bowels produces a cathartic operation, because there is a flow of water from the

capillary vessels to the cavity of the intestines. A very weak solution, on the contrary, will produce a diuretic effect, in consequence of the current being directed towards the blood from the cavity of the intestine.

Matteucci found that the current was influenced by the tissue constituting the membrane; if this be composed of skin, the movement is from the interior to the exterior surface, corresponding with the physiological action of the skin, which readily exhales, but does not so readily absorb. In the mucous membranes the action was found to be just the reverse,—that is, from the exterior to the interior; this movement accords likewise with their facility of absorption. The skin of the frog appears to offer an exception to this rule,—the current flowing most readily from its exterior to the interior; but it ceases to be an exception when it is remembered that the function of the skin of this animal is not to exhale, but to absorb; since it breathes, to a great extent, through its integument.

The cause of endosmose has not been discovered. It is probably dependent on some modification of chemical or molecular affinity.

3. Absorption.—This process is, properly speaking, a consequence of endosmose and imbibition. It can scarcely be called a proper *function*. Before the time of the Hunters, absorption was ascribed to the veins exclusively. Their discovery of the lymphatics led them to refer it exclusively to these vessels, whence they received the name of *absorbents*, a term which has been improperly continued till the present day. Absorption is a property common to all tissues, just as imbibition; the distinction depends on the direction of the circulating current.

The two conditions of absorption are, *first*, an endosmose, or imbibition; and *secondly*, transportation by a current. The laws regulating absorption are the following: 1st. It varies according to the vascularity of the tissue; the most vascular absorb most rapidly. 2d. The substance must be either soluble in the blood, or else capable of being suspended in it; hence oil cannot be taken up. The oily materials of the food thus escape absorption from the stomach, but in the duodenum they become mingled with the

pancreatic and biliary fluids, whereby they are converted into an emulsion which can then be taken up by the lacteals. It is uncertain whether *solid* matters, unless soluble, are ever absorbed. Mialhe denies it altogether; but certain facts go to show that some solids must certainly pass into the blood. It is well known that mercurial ointment—a preparation in which the mercury is chiefly in the state of very fine division—when rubbed upon the skin will occasion salivation; and globules of metallic mercury have even been detected in some of the organs after thus employing the ointment. 3d. The activity of absorption depends upon the activity of the circulation, and the direction of the fluids; hence it is more active in veins than in arteries. 4th. It is retarded by congestion of the tissue, because this interferes with the circulation of the part, and of course with the transportation of the matter to be absorbed. Absorption is inversely proportionate to the quantity of blood in the whole system, for the obvious reason that when the blood-vessels are full they can have no room for more; hence depletion always favours absorption. The fact is familiar to every practitioner, that in a high state of excitement medicines frequently fail to act from want of absorption, unless depletion be first practised. 5th. Temperature modifies absorption: it is increased by heat up to a certain point.

Of the different tissues of the body, the mucous membranes absorb most rapidly, because they are the most vascular. This is especially true of the bronchial and pulmonary mucous membrane; hence the facility of the introduction of medicines by the process of inhalation.

As regards *intestinal* absorption, very little more need be said. There can be no doubt that the fluids, and much of the soluble portion of the solid alimentary matter pass directly into the blood-vessels. The veins are chiefly concerned in this act of absorption, because their walls are thinner than those of the arteries; they are also distributed nearer the surface of the membrane, and the direction of their current,—the resistance constantly diminishing,—is more favourable to it

Lacteal absorption would appear to be chiefly concerned with

the oleaginous portions of the food, the milky colour of the chyle being due to the emulsion of fat. The lacteals take their origin in the *villi*, which are so abundant in the small intestine; each villus containing a single lacteal, which arises by several smaller branches, none of which have open mouths. The branches appear often to draw towards each other, forming loops. These loops are imbedded in a mass of *cells* at the extremity of the villus, which are the true agents of the selection of the nutritive materials from the chyme; so that it is by a process of *cell-growth* that lacteal absorption is really effected,—the cells filling up, bursting or deliquescing, and discharging their contents into the lacteals. This *selective* power of the cells is purely a vital property; it is analogous to that possessed by the cells of vegetables, which select from the pabulum common to all of them, the materials requisite for their own peculiar products.

The experiments of Tiedeman and Gmelin prove that the lacteals take up, almost exclusively, *nutritious* matters; while the veins absorb the odorous matters and saline substances. The colouring matters do not appear to be absorbed to any extent, but pass out of the system unchanged.

Absorption from the Skin and Pulmonary Surface.—The mucous membrane of the alimentary canal is not the only channel through which matters may be absorbed into the system. The skin, and the pulmonary mucous membrane are also capable of absorbing both liquids and vapours. In some of the lowest animals, and in the early condition of the highest, the external surface is as important a channel for absorption as the mucous membrane of the digestive canal.

A proof of the ability of the skin to absorb is given in the fact that intense thirst may be alleviated by immersing the body in water, or applying wet clothes to the body; also in life being prolonged in persons unable to swallow, by the immersion of the body in a bath of milk and water. So, again, it has been found that after bathing in infusions of madder, rhubarb, and turpentine, the urine was tinged with these substances; a garlic plaster affected the breath, although care was taken that the odour should

not be received into the lungs; gallic acid has been found in the urine after the external application of oak bark. In this way, also, we apply some of our medicines, as the mercurial ointment, &c.

As the epidermis affords a mechanical obstacle to absorption in the skin, it is removed by means of a blister in the *endermic* application of medicines. Absorption through the skin is chiefly accomplished by means of the *lymphatics*, because they are much more numerous near the surface than the veins, and their walls are thinner.

In the same way various matters may be introduced through the lungs; thus, if we breathe an atmosphere through which the vapour of turpentine is diffused, it soon produces the characteristic odour of violets in the urine. By the same means we produce an impression upon the system, through the inhalation of vapours; and it is probable that the various miasmata are thus introduced into the system.

The facility of absorption by the skin and lungs appears to be inversely proportionate to the quantity of fluid in the circulating vessels.

4. Diffusion of Gases.—This phenomena is also a modification of endosmose. It is common to all gases and vapours. If two gases of different densities be separated by a narrow tube, or by a membrane, they will be mutually diffused through each other, though very unequally; the law of diffusion being, according to Graham, that the diffusive power is inversely to the square root of the specific gravity. Thus, in the instance of hydrogen and oxygen, whose densities are to each other in the proportion of 1 to 16, the diffusive power of the former is four times greater than that of the latter. Graham and Valentin have determined the ratio between the oxygen inspired, and the carbonic acid expired from the lungs, to be as 1174 is to 1000. It is frequently supposed that it is this law which regulates the interchange between the oxygen and carbonic acid in the process of respiration; but in this case the gases are dissolved in the fluids, and must consequently obey rather the laws of endosmose; since the "law of diffusion" has reference only to dry membranes.

5. Exhalation.—This physical process is the reverse of absorption. Like the latter, it occurs in every part of the body. Although the blood is contained in a perfectly closed system of vessels, there is a constant escape, by exhalation, of a large amount of its watery portion through the various membranes. The quantity thus thrown off by the skin and lungs together, varies from $1\frac{5}{8}$ to 5 pounds a day. True perspiration, however, is rather the result of the secretory action of the sudoriparous glands.

The effect of exhalation is to produce a partial vacuum within the vessels; this is partially compensated for by venous absorption; hence it is highly probably that the venous circulation is influenced by it, just as the circulation of the sap in plants is affected by the rapidity of the exhalation from the leaves.

6. Elasticity.—This physical property exists in certain animal tissues, and subserves very important purposes. It is witnessed in the elastic fibrous tissue, which is composed of curling filaments. This tissue enters into the composition of the ligamentum nuchæ, the ligamentum subflava of the spine, the middle coat of the arteries, the vocal chords, the fibrous bands of the trachea and bronchi. Its function is to economise vital force; thus the ligamentum nuchæ, especially of quadrupeds, by sustaining the weight of the head by its elasticity, saves an immense expenditure of muscular power. The serous membranes possess elasticity, as is witnessed in the distension, and subsequent receding of the peritoneum in pregnancy and dropsy. The elasticity of cartilage enables it when interposed between the joints, to act as springs, taking off the concussion of blows or falls.

In elastic bodies, the reaction or recoil is always equal to the impinging force.

7. Electrical Phenomena.—The physical phenomena of electricity are manifested to a great extent by animals, and the results of recent experiments upon animal electricity entitle them to a consideration under the present head. It may be assumed that an electrical atmosphere surrounds the molecules of every body in nature. Electricity may exist in two distinct conditions, either in a state of rest, termed *latent* or *statical*, or secondly, in

a state of motion, termed *dynamical* electricity. The phenomena of electricity depend upon the disturbance of its statical or equilibrium condition, or rather upon the disturbance of the molecular condition of the body. The most common cause of this disturbance is chemical action; but whatever produces a change in the molecules will excite electricity, as friction, change of temperature, or muscular movement.

It has already been shown that every life-action is accompanied by chemical changes; since these are the chief excitors of electrical phenomena, it must follow that every living being is *electro-genetic*, or a source of electricity. The whole subject of animal electricity is yet undergoing investigation, and is to a great extent in an unsettled state. The following may be regarded as a summary of its established facts.

Dynamic electricity is found to exist in the highest degree of tension in certain animals, as the torpedo or electric ray, and gymnotus or electric eel, in which there is a special apparatus provided for the purpose. The electric organs consist of piles of cells containing a semi-gelatinous fluid, bearing considerable resemblance to an artificial galvanic battery. These organs are under the control of the animal's will; they are connected with certain nerves as the par vagum, the facial, or the spinal; but no special nerve appears to be required. The intensity of the electric force in these animals is dependent upon their organic and chemical actions, since the shock is always greatest when they are active and vigorous, and becomes feeble when they are exhausted. The electricity thus excited is not destined for any special function, but serves only as a means of defence, or prehension of prey.

Muscular contractions are excited by electricity. This was shown by the original experiment of Galvani; but so sensitive is a muscle to electrical excitement, that the freshly-dissected leg of a frog is now employed as the most delicate galvanoscope that we possess. Muscular contractions may be excited, independently of any metallic contact, by simple contact with a living structure, thus proving the existence of electricity in the muscle: this is shown by holding the galvanoscopic frog in contact with the

tongue, when contraction of the frog's leg will take place. The same result is produced by seizing with one hand the head of a recently-killed ox, and taking hold of the tongue with the other hand, moistened with a saline solution,—a distinct contraction is observed.

Matteucci's experiments prove the existence of two distinct currents in every muscle, one passing from the interior to the exterior, and another traversing it lengthwise from the insertion of the tendon to its origin. The structure of a muscle, as regards its ultimate composition of cells, is very similar to that of the electric organs of the torpedo and gymnotus. All the electric forces of animals are of very low tension.

The effect produced upon an animal by an electrical current varies according as it is made to pass from the central origin of a nerve to its periphery, or *vice versâ;* in the former case, or that of the direct current, contraction occurs at the moment of contact of the opposite poles; in the latter instance, or the reverse current, contraction takes place at the moment of their separation. The strongest contraction occurs from the direct current, but the animal evinces least pain; the reverse current occasions least contraction, but most pain.

A muscle or nerve, by long or repeated contractions, loses its contractile power, but recovers it by repose. A nerve retains its power longest at its periphery, and loses it soonest at its origin. The direct current exhausts the contractile power of the muscle, and if continued, produces paralysis. The inverse current will restore the power lost by the direct current, and, if continued, will produce tetanic spasms. Hence, in the treatment of paralysis by electricity, the inverse current should always be employed. Interrupted currents only produce local effects; they never prove curative in paralysis.

There are also other electrical currents in the body besides those of the muscles; one between the liver and the stomach,—the secretion of the former being alkaline, that of the latter acid; another between the mucous membrane and the skin,—the former being generally alkaline, and the latter acid. The electricity of

the human body is nearly always positive; but if the secretion of the skin becomes alkaline, it is reversed, and becomes negative; occasionally it is neutral.

The *origin* of animal electricity has given rise to much speculation. Liebig ascribes it to the chemical reaction between the acids existing in the juice of muscles (contained in the cells of the fibrillæ), and the alkalies of the blood,—the two being separated only by the very delicate capillary membrane. Matteucci supposes it to be the result of the nutritive actions of the muscles. Both theories are probably correct. Another source may be the constant combination between the hydro-carbon and oxygen, and also from the chemical actions occurring in secretion.

The most interesting question connected with this subject is that of the identity of electricity and the nervous force. It is well known that there are two distinct nervous currents in animals, one going from the anterior spinal centres to the periphery of the body, producing contraction, and the second, proceeding from the periphery of the posterior centres, producing no contraction, but only sensation. Now, as just shown, we can produce precisely similar effects by the direct and reverse electric currents. This, however, proves but little, since a mechanical or chemical irritant will produce the same results. There is certainly a strong analogy between the two forces, but no proof of their positive identity. Indeed, the nerves are rather bad conductors of electricity,—inferior to the muscles. Again, a ligature upon a nerve will not prevent the passage of an electric current, but it will arrest the nervous current.

It is highly probable that the numerous electrical currents developed in the animal economy are applied to some practical purpose; and it has been supposed that it was in some undefined way converted into the nervous force. Other authorities, however, regard the nerve-force as an independent one, and consider the electricity to be the *effect*, and not the *cause* of any function.

In relation to the *therapeutic* effects of electricity, it is an agent which but too frequently disappoints expectations. Those who

have employed it most, regard it as applicable to but very few disorders, and those of a nervous character.

Under the head of the Physical Actions of the Economy might be very properly classed the physical phenomena of Hearing, Vision, and the Voice, since the organs of each of them are constructed upon purely physical principles. They will be more conveniently treated of, however, in the latter part of the work.

CHAPTER IV.

DYNAMICAL AND MECHANICAL ACTIONS OF THE ORGANISM.

By the term *animal dynamics* is understood those active phenomena of life which belong exclusively to animals, and distinguish them from the vegetable world. The force which produces these actions is termed *the dynamic* or *excito-motor* force; it is generated in the cerebro-spinal apparatus—its special excitor, and manifests itself chiefly through the muscles, its special instruments. All the proper animal functions, or *functions of relation* as they are sometimes named, are inseparably connected with a nervous system, and they display themselves in the various active movements of the body, either guided by the will and controlled by the intelligence, or else placed beyond the influence of volition, and directed only by a force residing in the nerve-ganglia, as is witnessed in the reflex actions.

The dynamic force, when acting through its appropriate instruments, constitutes the *animal mechanics* of the economy. The great object of this force is to maintain the requisite conditions for the display of the organic or vital force, which latter, it will now be understood, ranks first in importance to the living being, and which only manifests itself in the molecules, never displaying any mechanical power.

In animal mechanics the power resides in the instruments—the

bones, muscles, and ligaments; while the force which puts these instruments in motion, is generated by the cerebro-spinal axis. It is, however, to be observed that muscular contractility—a power inherent in sarcous tissue, and entirely independent of nervous influence—will materially aid the proper dynamic force in producing the different movements of living beings. Animal mechanics may consequently be deficient in two ways; either from a defect in the nerve-centres which generate the dynamic force, or from a diseased condition of the muscles or bones.

The dynamic forces of the body are too much overlooked in medicine; very often they alone are at fault; hence the importance of properly understanding them. The apparatus for generating these forces, as already mentioned, consists of the cerebro-spinal axis;—the spinal cord regulating the movements of the trunk and extremities; the medulla oblongata, the involuntary movements, especially the respiratory; and the cerebellum co-ordinating the voluntary motions. This apparatus is composed of numerous, distinct, and independent centres; no less than 128 distinct centres entering into the composition of the spinal cord; while the medulla oblongata comprises at least four separate centres. The complete independence of these different nerve-centres explains many curious pathological facts, such as the paralysis of a single muscle, or even of a few fibres of a muscle, as has occurred in the deltoid; also, the loss of the voice, while the intellectual faculties have continued unimpaired. The force thus generated by the spinal cord is placed under the control of the will acting through the medium of the cerebrum and of the cerebellum, which harmonizes all the voluntary movements. The perfection of the animal machine, and its superiority over every artificial one are owing to the numerous independent sources of its acting force, together with the great variety of its movements.

The method of estimating the dynamic forces is by the *effects* which they produce. The application of this rule, in the estimation of human dynamics, is made in a variety of ways. Desaguilliers and Bernouilli calculated that it was equivalent to a force that would raise ten million of pounds, one foot, in seventeen

hours. Modern engineers make it much higher,—equal to a force that would raise ten pounds, ten feet, every second, for ten consecutive hours; this is equivalent to 3,600,000 lbs.,—rather too high an estimate. Coulomb's estimate was, that a man weighing 155 lbs., could mount a stairs at the rate of forty-five feet in a minute, for ten hours; in doing which, he will expend a force equal to 4,100,000 lbs. In animal mechanics there is undoubtedly a great saving of dynamic force, owing to the compound levers of the body, so that the enormous amount of mechanical power shown by the above results, is not to be regarded as indicating an actual expenditure of that amount of force; probably one-half is saved. Again, the *direction* in which these forces are exerted causes a vast difference in the results; thus, a healthy adult man may easily walk on a level road a distance of thirty miles in a day; whilst he could not perform more than two miles on a perpendicular stairs in the same time.

The superiority of human dynamics over those of artificial machinery, has been attempted to be illustrated by the following comparison: A man consumes in ten hours from 1000 to 1500 grains of carbon, during this time he will carry his own weight a distance of thirty miles; this is equal to a mechanical power of two or three millions of pounds. In the display of an equal amount of power, a locomotive engine would consume 15 pounds, or 86,400 grains of carbon.

Whenever these acting forces of the economy become exhausted, the sense of *fatigue* is experienced, which is intended to warn against undue exertion. The more rapid their expenditure, the quicker is the exhaustion, because the consumption of the materials cannot keep pace with the repair. This is constantly exemplified in the rapid fatigue and exhaustion attendant upon violent muscular exertions. A labourer if heavily loaded gives out much sooner than one lightly burdened, although the latter may actually expend a greater amount of force. Another fact of practical importance is that in proportion to the expenditure of the dynamic force by the external muscles, will be the exhaustion of the internal forces, or those connected with the organic functions.

Hence enfeebled digestion is a frequent consequence of such over exertions.

The dynamic force is excited into action by various modes: *first*, through the excito-motor or reflex actions; in these the primary impression is made upon some sentient surface, where it is transmitted to the posterior spinal centres, and then conveyed to the anterior centres, when they excite muscular contractions; *secondly*, by volition, the brain acting probably through the commissural fibres of the spinal cord; *thirdly*, by the emotions and passions, which often act independently of the will, when under powerful excitement.

The display of the dynamic forces is most intimately connected with the healthy condition of the nerve-centres, the slightest pathological change being sufficient to arrest them. A little softening, or a slight effusion into the spinal marrow, may produce extreme debility, or even complete paralysis. But there is likewise a great natural difference in individuals, as respects the endowment of this force, some possessing it to a very great degree, while others are constitutionally feeble. Hence the absurdity of framing any general law as to the amount of mechanical power individuals are capable of exhibiting. The most serious mistakes are committed by persons of feeble dynamic capacity, in attempting to perform feats which have been witnessed in others, of naturally greater endowment in this respect. As has been aptly observed, as well might an engine of one-horse power be expected to do the work of one of one hundred-horse power. A most important application of this principle is to be made to invalids of feeble strength, who are too frequently recommended, indiscriminately, to resort to active exercise, for the purpose of increasing their strength. In many such cases, exertion only increases the debility by still farther exhausting the forces. Here, the proper remedy is repose, by which alone the dynamic forces can be recruited; and in certain cases the repose must be absolute, and continued for a considerable time.

The *source* of the dynamic forces is to be traced possibly to caloric. Many years ago Montgolfier asserted the identity of

caloric and mechanic force; and, at present, the disappearance of sensible heat in the conversion of water into steam is explained not upon the theory of *latent heat*, but upon the conversion of heat into mechanic force. M. Joule has, in fact, established the *law* that the degree of heat required to raise 15 grains of water one degree, is equivalent to the mechanic force necessary to elevate a weight of 13½ ounces one metre (39·37 inches). It is well known that combustion is constantly going on in the animal economy between the oxygen taken in by inspiration, and the hydro-carbon of the food and of the tissues; and also that this combustion is proportionate to the activity of the respiration. Hence, any cause that reduces the function of respiration will diminish the dynamic force. But there must also be a proper amount of the calorifacient elements of the food to furnish the materials for combustion; consequently an impoverished diet, or a disordered condition of the digestive functions, will likewise impair this force. Since then, the dynamic force is the result of the chemical changes, producing the destruction and disintegration of the materials of the tissues, it can be readily understood how exhaustion and fatigue should occur from two sources,—first, the direct expenditure of power, and secondly, an imperfect supply of proper food to reconstitute the wasted materials. Under this head might be noticed the great importance of a proper nutritious diet for labourers.

Before, however, caloric can manifest itself through the nerve-centres, it must first be converted into nerve-force; and as to the *mode* by which this change (if it actually does occur) is produced, nothing is definitely known; it may possibly be the special office of the spinal marrow to convert caloric into nerve-force; but this is merely conjectural.

Many important functions of the system are executed by the dynamic forces, as respiration, with its modifications of sneezing, yawning, and coughing, together with the voice and speech; the circulation of the blood; many of the movements of digestion; the expulsive movements from the different cavities of the body, as the bladder and uterus; and finally, locomotion, including

walking, running, leaping, dancing, &c., and all the various movements of the body concerned in raising weights, or overcoming resistances. The functions of Respiration and Circulation will be treated of under separate sections; a few remarks in relation to the other functions above alluded to may not be out of place under the present head.

The dynamic movements belonging to *Digestion* comprise mastication, deglutition, peristaltic movements of the stomach and bowels, and the expulsive efforts of the rectum and ducts opening into the alimentary canal. The dynamic force exerted in mastication is often very considerable; it is particularly well seen in carnivorous animals. Mastication is accomplished by the voluntary muscles,—chiefly the masseters, which, in some animals, are very strongly developed; in cases of extreme debility this power fails, as is shown by the falling of the jaw. Deglutition is accomplished by the involuntary muscles, through reflex action; the powers of deglutition sometimes fail in disease, constituting *dysphagia*. In the same manner, the peristaltic action of the stomach may be interfered with, producing one form of dyspepsia; such cases may sometimes be traced to a deranged condition of one or two of the spinal centres. If the peristaltic condition of the bowels be affected, constipation will be a frequent result, or else an undue accumulation of flatus; these latter results are very apt to occur in old persons, in whom there is this habitual deficiency of peristaltic action. Other pathological conditions of the dynamic forces of digestion are regurgitation, nervous vomiting, spasms of the stomach, and tenesmus.

The *locomotive* movements of the body are all under the influence of the dynamic force, and are performed by the muscles, as its appropriate agents. The amount of dynamic force expended in mechanical labour of different kinds has already been alluded to. Locomotion is liable to various pathological conditions, depending either upon a disordered state of the dynamic force, or upon some defect in the muscular system, such as softening, as occurs in scurvy. An entire loss of dynamic force constitutes palsy, in which either the cerebral or spinal centres, or both, may

be involved. Sometimes there is an excess of dynamic power, constituting *spasm.* In hysteria there is often suddenly developed an immense dynamic force. Again, this force may be perverted in its action, as is witnessed in chorea, catalepsy, and epilepsy. Finally, there may be a general loss of the dynamic forces, as is frequently seen in certain forms of fever denominated *pernicious* or *adynamic,* in which the fever-poison has acted with unwonted energy upon the nervous centres, producing an exhaustion of their power.

SECTION I.

RESPIRATION.

The essential object of the function of Respiration is to free the blood from carbonic acid, and to introduce into it oxygen from the surrounding medium. The necessity of this function to all organized beings is inferred from the fact that every plant and animal exhibits it, though in different modes.

The respiration of vegetables is precisely similar to that of animals; that is, they are constantly giving off carbonic acid, and absorbing oxygen. But this process is frequently not obvious, in consequence of another function which they perform, namely, that of the fixation of carbon by decomposing the carbonic acid of the air, appropriating the carbon as their food, and liberating the oxygen. This last process is the *digestion* of plants, and is accomplished by the leaves, and only under the stimulus of solar light; whilst the process of respiration goes on as well in the dark as in the light. A healthy plant, will, however, *fix* much more carbon than it sets free by respiration, so that the general effect of vegetation is to purify the atmosphere from the carbonic acid produced by animal respiration, combustion, &c.

The necessity of respiration in animals is still more evident. The feeling appears to be an instinctive one, and although very partially under control, yet in the higher animals, and in man, it

becomes in a few minutes irresistible—the will ceasing to be able to prevent the inspiratory movement. If the admission of air into the lungs be prevented by any means, the respiratory efforts become at first very violent; these are followed by irregular convulsive movements, which shortly terminate in insensibility, producing asphyxia. This condition generally comes on, in warm-blooded animals, within ten minutes; but in the cold-blooded, a much longer suspension may be borne with impunity, and even by warm-blooded animals in the hybernating condition, by which the activity of these functions is much reduced.

It is not so much the want of the introduction of oxygen into the lungs, as of the excretion of carbonic acid from them, that proves the source of difficulty in asphyxia; this latter agent seeming to exert a directly poisonous effect upon the system, if not properly eliminated. The source of this carbonic acid in venous blood is threefold. In the first place, as has been already shown, all the various acts of life in the animal are attended by a waste or disintegration of the different tissues. One of the products of this decomposition is carbonic acid :—this is the ordinary waste of the tissues. A second source of carbonic acid in venous blood arises from the rapid changes which take place in the muscles and nerves during their period of activity; these changes being in exact proportion to the degree of this activity. Now, oxygen, as has been previously shown, is indispensable, both for muscular and nervous action; and from its union with the elements of these tissues, carbonic acid, among other products, results. In those animals whose muscular and nervous structure are comparatively small, the amount of carbonic acid generated is proportionally minute; but whenever we find the muscular powers well developed, we invariably have a large amount of carbonic acid set free by the lungs. This is well seen in insects, some of which are remarkable for their muscular powers; thus, a single humble-bee was found to produce as much carbonic acid in the course of one hour, during which it was in a state of violent excitement from its capture, as it did afterwards, when calm, in the course of twenty-four hours. The third source of the carbonic acid is the

result of animal heat, which is peculiar to warm-blooded animals, and depends upon the combustion of most of the hydro-carbons of the food,—they entering into distinct combination with oxygen, and producing carbonic acid as a result.

The amount of carbonic acid produced directly from the elements of the food will vary very much in different animals, or in different states of the same animal. Thus, in the carnivora, which are generally very active, the greatest part of it is derived from the waste of the tissues; whilst, in the herbivora, which are inert and sluggish, the quantity derived from this source is comparatively small; hence much of their food is appropriated as *fuel* for the generation of animal heat, so as to supply the deficiency. In man, and other animals capable of a diversity of habits, we find both sources in operation,—one serving as the complement of the other. When the external temperature sinks, the direct combination of the food with oxygen will be increased, in order to supply the deficiency; and whenever the supply of food is too little, the fat which has been stored up is drawn upon, and if this be exhausted, the animal dies of cold.

The twofold effect of the introduction of oxygen into the lungs, and the extrication of carbonic acid from them, is accomplished by the same act of respiration, by virtue of the law of endosmose, or the "mutual diffusion of gases." Thus, if a bladder containing venous blood be suspended in a receiver containing oxygen, the blood will soon assume the arterial hue, in consequence of the carbonic acid passing out through the membrane, while oxygen passes in, just as two liquids of different densities would act. This is precisely the condition in the respiratory organs of animals; by means of the minute ramifications of the pulmonary capillaries, an immense surface of blood is brought into relation with the atmospheric oxygen,—a delicate membrane only being interposed, which, as we have seen, offers no resistance to their mutual transmission.

Such, then, is the *essential* part of the function of respiration; but the dynamic forces of the heart and of the muscles of respiration are also requisite,—the former to supply the constant renewal

of blood to the pulmonary capillaries; the latter to insure the requisite supply of air in the pulmonary vesicles. The dynamic forces of Respiration will be presently noticed.

Different Forms of the Respiratory Apparatus.—In the very lowest order of animals inhabiting the water, there is no special organ of respiration, the integument serving the purpose of an aerating membrane, through which the air contained in the liquid comes in contact with the fluids of the body. The renewal of the fluid in contact with the animal, is accomplished by means of cilia, which appear also to serve as organs of prehension and locomotion. Sometimes, also, the internal prolongation of the integument constituting its stomach acts as the aerating membrane, the air being furnished from the water which fills the cavity.

In the mollusca there are distinct organs of respiration. As most of them are aquatic, they are furnished with *gills*, which differ a good deal in their complexity. In these, also, the constant renewal of the water is provided for by ciliary movement. In the land mollusks, as the snail, there is usually a simple cavity situated in the back, communicating directly with the air through an aperture in the skin, and having a network of vessels on its walls.

In many of the lower articulata the respiration is carried on through the tegumentary membrane,—as in the tape-worm. In the marine worms there is a series of gill-tufts along the body, in which the blood is brought into relation with the surrounding medium. The crustaceæ, as the crab, breathe by gills, which are enclosed within a sort of doubling of the shell on the under surface of the body, and a constant stream of water is maintained through this. The land-crab has also gills, though it is an air-breathing animal, the proper amount of moisture necessary for the play of the gills being provided for by means of an apparatus within the gill-cavity.

In insects, the respiratory organs consist of a number of small sacs, called *spiracles,* distributed along each side of the body, and communicating with two tubes called *tracheæ,* which extend the whole length of the body. Occasional dilatations are met with in

these tubes, which act as reservoirs for air in those insects which make long flights, so as to diminish the specific gravity of their body.

The gills of fishes resemble, essentially, those of mollusks, but they are much more perfect. The water is first taken in at the mouth, then forced, by muscular contraction, through an aperture on each side, into the gill-cavity. Here, the aerating process takes place, after which the water is expelled through the outward openings at the back of the neck. The reason why fishes die so soon when taken from the water, is chiefly on account of the drying up of the membrane of the gills by the air, preventing thereby the aeration of the blood; and also on account of the flapping together of the filaments of the gills, by which a sufficiently large surface is prevented being exposed to the air. Hence we find those fishes living the longest in which the external gill-openings are very small. Very often the supply of air in the water is not sufficient for fishes;—this causes them to rise to the surface, and swallow air, which passes into the intestines, the surface of which appears to act as a respiratory membrane. The *air-bladder* in fishes, has often no connexion whatever with their respiratory apparatus, being entirely closed. It seems designed to regulate their specific gravity. In other cases, however, it forms a communication with the intestinal canal, and is thus concerned in respiration.

In reptiles, although the lungs are large sacs, yet from their not being much subdivided, but a small amount of surface is exposed; this is in character with the low activity of their functions. These lungs are not filled by the mere act of inspiration, as in other animals, but by an act of swallowing; a single inflation thus made being sufficient to last the animal a considerable time. When the air thus taken in has become exhausted, it is returned by the aid of muscular pressure, and its exit through their narrow glottis is accompanied by their peculiar *hissing* noise.

In birds, whose respiration is very active, the lungs are minutely subdivided, and likewise communicate with air-sacs placed in different parts of the body, and in most birds, with the cavities

of the bones, the lining membrane of which serves as an aerating surface. This arrangement also diminishes their specific gravity, and facilitates their flight. The natural condition of the lungs of birds is that of distention; in consequence of the elasticity of their tissue, it requires muscular power to empty them.

It is in the mammalia, and in man, that we find the respiratory apparatus most complete, and the ultimate divisions of the lungs most minute. The lungs are suspended in a perfectly closed cavity—*the thorax*, with the sides of which they are, under ordinary circumstances, always in contact. The capacity of the thorax, however, is susceptible of great change under the action of the intercostal and abdominal muscles, and diaphragm. When the chest is expanded by muscular action, the air within the lungs, by virtue of its elasticity, causes them to dilate, so as to fill up the vacuum thus created; and this immediately causes the air to rush in through the trachea. The complete dependence of the expansion of the lungs upon the perfection of the vacuum of the chest is well shown by the effects of admitting air into the pleural cavity, either by an external opening, as a punctured wound, or by internal communication formed between the lungs and pleural cavity; in either case, instant collapse of the lungs takes place; and if it occurs in both sides, asphyxia results. The expulsion of the air from the lungs is caused chiefly by the elasticity of the cartilages of the ribs.

The muscles of *inspiration* are the scaleni, the intercostals, and the diaphragm; the elevation of the ribs being also assisted by some of the muscles of the scapula. But in ordinary tranquil breathing, the diaphragm is the chief agent of inspiration; its contraction producing a change in its position from its highly arched shape, to nearly a horizontal one. This enlarges the cavity of the thorax, and at the same time presses upon the abdominal viscera, causing them to protrude forward. The movement of *expiration* is effected by the contraction of the abdominal muscles, aided by the elasticity of the cartilages of the ribs.

The larger bronchial tubes are cartilaginous. The smaller ones are not believed to be so, although retaining their circular form;

they possess, however, decided contractility, which is probably due to a fibrous structure, having the properties of the non-striated muscles. This contractility may be called into action by various stimuli applied directly to their walls, though not readily by stimulating their nerves. The disorder termed *spasmodic asthma* consists in a spasmodic contraction of the minute bronchi, dependent often upon remote causes. This is confirmed by the fact that the contractility of these parts is much diminished by certain narcotics, as belladonna and stramonium, substances which are well known to be beneficial in the treatment of this affection.

The diameter of the ultimate air-cells of the human lung varies from the 1-200th, to the 1-70th of an inch. Their form is irregular,—their walls being flattened together. Each ultimate bronchial tube terminates in a cluster of these vesicles, every one in the group thus formed freely communicating with its fellow,—all being lined with a continuation of the lining membrane of the bronchus. Between the air-cells there is a delicate fibrous tissue of an elastic character. It is through these minute air-cells, that the blood comes into relation with the air; the extremely minute capillary plexus of the pulmonary artery being placed between the walls of the air-cells, so that the blood in them is aerated on both sides. It has been calculated by M. Rochoux that each ultimate bronchus terminates in about 18,000 air-cells, and that the total number of these cells in the lungs amounts to six hundred millions; and so intricate and minute is the capillary plexus, that Munroe calculated that there was a superficies of vascular surface exposed to aeration, equal to several hundred square feet.

Dynamical Phenomena of Respiration.—The mechanical actions of respiration consist in the two alternating movements of inspiration and expiration; and as these are, to a great extent, accomplished by muscular contraction, they involve a necessary expenditure of dynamic force. The resistance to be overcome in *inspiration* is the elasticity of the ribs and cartilages, together with that of the tissue of the lungs; the former, according to the experiments of Mr. Hutchinson, is equivalent to 100 lbs.; the latter he estimates at 80 to 150 lbs.; so that the dynamic force

required for each inspiratory act amounts to 180 to 250 lbs.; and this is repeated, throughout the lifetime, from 14 to 18 times a minute. The act of *expiration*, though materially aided by the elasticity of the cartilages of the ribs and of the tissue of the lungs, is likewise accompanied by the loss of dynamic force, since the abdominal muscles are brought into action to draw down the ribs, and compress the abdomen, so as to force the viscera against the relaxed diaphragm, and thus diminish the cavity of the thorax from below. In a *forced* respiration, the amount of dynamic force expended is very much increased.

Coughing may be regarded as a modification of the respiratory action, since it is produced by violent efforts of the respiratory muscles. Its object is to rid the air-passages of irritating matter; hence, coughing is always present whenever there is bronchial irritation. In great debility, where the dynamic forces are low, there is often not sufficient strength to cough up the secreted matters from the respiratory passages. This is witnessed in the closing stages of pectoral diseases,—the accumulated mucus, in fact, producing suffocation.

At each respiration only a portion of the air within the lungs undergoes a change. According to the experiments of Mr. Coathupe, about 266 cubic feet, or 460·224 cubic inches of air, pass through the lungs of an average sized man, in 24 hours. Reckoning the average number of inspirations at 16 in a minute, this would give 20 to 25 cubic inches as the amount inhaled in each; the same quantity being also given out at every expiration. The quantity of air thus habitually changed in every act of ordinary respiration is named, by Mr. Hutchinson, *breathing air*. The quantity over and above this, which can be taken into the lungs by the deepest inspiration, he names *complemental air*. The air remaining in the lungs after ordinary expiration, is estimated at about 100 cubic inches; that portion of it which may be expelled by a forced expiration, is called, by Mr. Hutchinson, *reserve air;* but even after the most powerful expiratory effort, there still remains in the lungs a certain amount of air, termed *residual air*, its quantity depending chiefly upon the absolute size of the chest,

and varies considerably in different cases. Upon the residual air depends the lightness of the lungs, and their tendency to float upon water when once they have been inflated by a full inspiration; this fact has given foundation to the hydrostatic test in cases of infanticide; it is also the cause of the resonance of the chest on percussion.

The capacity of the lungs varies very much in different individuals, and is not so much regulated by the mere size of the chest as is commonly supposed. Mr. Hutchinson's experiments with the spirometer have established some interesting conclusions with regard to this subject. He has ascertained that in health there exists a very constant relation between what he terms the "vital capacity" of an individual, or the quantity of air which he can force out of his chest by the strongest expiration after the deepest inspiration, and his height; the mean *capacity* of 172 males under the height of 5 feet 8 inches, being 220 cubic inches; whilst that of 82 males between 5 feet 11 inches and 6 feet, is 255 cubic inches. In every additional inch of height, from 5 to 6 feet, eight additional cubic inches of air are given out by a forced expiration. In fat persons the capacity is lower than in others. This method of estimating the "capacity" of the lungs is now much employed as a valuable aid in diagnosis.

The average number of respirations per minute in a healthy adult, is from fourteen to eighteen. The most of these are performed simply by the diaphragm, but at about every *fifth* inspiration a more decided movement occurs, attended with an elevation of the ribs. The frequency of the respiration is liable to great modification from various causes, as exercise, emotion, action of narcotics, apoplexy, &c. It is always accelerated by diseases which interfere with the function of the lungs—as pneumonia, pleurisy, &c. Thus, while the usual proportion in health between the respiration and the pulse, is as one to four and a half, or five, it may become in pneumonia, as one to three, or even one to two. The same acceleration takes place also where other parts concerned in the mechanism of respiration are affected, as the pleura, the ribs, the muscles (as in rheumatism), the abdominal viscera, and the peritoneum. In all these

cases, the deficiency in the amount of the respiratory movements is attempted to be made up by their frequency.

As already shown, the movements of respiration are involuntary, to a great extent at least,—being performed through *reflex* action. The great centre of these movements is the medulla oblongata, particularly the corpus olivare, which might be denominated the *respiratory ganglion*. The brain may be removed, as well as the spinal cord, below the medulla oblongata, and respiration will still go on. The chief excitor or afferent nerves are the par vagum, which conveys the impression from the lungs themselves, and the sensory branches of the fifth, which convey sensations from the general surface. This is well seen in the first efforts made to breathe by a new-born-child, and the effects of cold water suddenly thrown upon the surface, and of irritation of the skin in cases of narcotic poisoning. The efferent or motor nerves are chiefly the phrenic and intercostals.

It is to the *limited* control which the will has over the respiratory movements, that the faculty of speech, and its modifications of singing, &c., are due.

So long as the function of the medulla oblongata is not interfered with, respiration will go on; thus it proceeds with perfect regularity in sleep, because the medulla oblongata is always active, though the brain may be perfectly quiescent. In apoplexy and in narcotic poisoning, the breathing becomes affected because the influence is gradually extended from the brain to the medulla oblongata. When the respiration becomes suspended from the effects of narcotics, life may often be saved by resorting to artificial respiration, by which the circulation may be kept up until the poison has passed off from the system. The *residuary* air, it is supposed, will support life about three minutes.

In typhoid fevers the respiration becomes very much reduced in frequency,—probably from a poisonous effect produced on the blood, which, in consequence, does not stimulate the nervous centres to a sufficient degree.

Chemical Effects of Respiration.—It was formerly supposed that the venous blood arrived in the lungs charged with carbon, and

that here a union was effected between this and the oxygen of the air, which was the source of the carbonic acid exhaled. This idea, however, is no longer tenable, since it is proved that carbonic acid will be given out from the lungs, if an animal be made to breathe pure hydrogen, or nitrogen. The true statement is that the venous blood is charged with *carbonic acid*, which has been formed in the systemic capillaries, or rather in the ultimate molecules of the body, in the various chemical actions of the system, and that, in the lungs, this carbonic acid is displaced by the oxygen absorbed. The atmosphere is composed of about twenty-one per cent. of oxygen by measure, and seventy-nine of nitrogen, or over three-fourths: the only office of the nitrogen being, so far as known, to dilute the oxygen.

The relative proportions of oxygen absorbed and of carbonic acid given out, though not invariably the same, may be stated to follow the general "law of the diffusion of gases," already alluded to, which is that they are inversely as the square roots of their specific gravities. This law applied to the case of oxygen and carbonic acid gives us the proportion of 1174 to 1000, which corresponds very closely with the relative proportions of these two gases interchanged in respiration. From this it will be seen that as there are 1174 parts of oxygen taken in, and 1000 parts thrown off in the form of carbonic acid, there will remain 174, or nearly 15 per cent., to be accounted for in other ways. Some of this oxygen combines with the sulphur and phosphorus of the body, to form sulphuric and phosphoric acids, which again unite with bases to form salts; and some of it unites with the hydrogen of the oily matters to form water, which is exhaled from the lungs.

The actual amount of carbonic acid exhaled during a given time, varies according to several circumstances, as age, sex, temperature, period of the day, and exercise. The average quantity exhaled in twenty-four hours is variously estimated. Liebig calculated it by comparing the amount of carbon taken in as food with that contained in the fæces and urine, the difference being set down to the account of respiration. His experiments were made on individuals subjected to constant exercise. The result seems

inordinately high—13·9 ounces of solid carbon per diem, as thus extricated from the lungs and skin. According to Prof. Scharling's experiments, which were conducted upon individuals in a state of rest, the total amount of carbon set free from the system, both by the lungs and skin, in twenty-four hours, is from 7 to 8 ounces. Dr. Carpenter assumes 10 ounces, or 4800 grains of carbon, to express the average amount excreted from the lungs and skin of a male adult, using active exercise, in twenty-four hours; this would require nearly 37,000 cubic inches, or more than 21 cubic feet of carbonic acid to be generated. Of this, about 16 cubic feet are probably extricated from the lungs; but 10 cubic feet per day would, probably, more nearly express the average.

The amount of carbonic acid exhaled is very much increased by a reduction of temperature; thus, at 32° it is more than double what it is at 100°. Exercise also augments it, whilst sleep diminishes it: thus a person who was excreting 145 grains of carbon per hour, while fasting and at rest, excreted 165 after dinner, and 190 after breakfast and a walk; but only 100 when asleep. The exhalation is also greater in males than in females of the same age, except in childhood. In males, the quantity increases regularly from eight to thirty years; it then remains stationary till forty; after which it regularly diminishes to extreme age, when it is not greater than at ten years. Great muscular development, however, will always cause the amount excreted to exceed this average, while a deficient development will produce a diminution of it. In females, there is a proportional increase till puberty, when it is suddenly arrested, the quantity remaining stationary so long as menstruation continues regular: the average quantity being about 100 grains of carbon per hour. When menstruation ceases, it undergoes a decided increase up to the age of fifty, after which it diminishes, as in men. Should any interruption to the catamenia occur, as in pregnancy and lactation, immediately there is the same increase in the exhalation.

The whole quantity of air which passes through the lungs in twenty-four hours, is estimated at about 266 cubic feet; on comparing this with the amount of carbonic acid excreted under similar

circumstances, we find the proportion of the latter to average about four per cent. of the whole. This proportion, however, may rise much higher, in consequence of a laborious respiration. Again, it may be reduced materially by the presence of a certain amount of carbonic acid already existing in the air which is respired. Hence the importance of free ventilation, to insure a proper aeration of the blood; the presence of a very small amount of carbonic acid in the air being sufficient to prevent the excretion of the due amount of it from the lungs. An animal may be kept alive in a limited quantity of air until nearly all its oxygen is consumed, provided means be taken to remove the carbonic acid, as fast as it is generated.

The nitrogen of the air is but slightly affected in respiration. It is constantly absorbed, and constantly given out again. In animals, Dr. Edwards found that rather more was given out than was absorbed, during the summer months; but that in winter, the reverse took place.

As regards the changes produced in the blood by respiration, it will be shown hereafter, under the head of Circulation, that the proportions of oxygen and carbonic acid differ very much in arterial and venous blood. The results of Magnus' experiments give us the following summary:

	Arterial Blood.	Venous Blood.
Oxygen,	23·2	15·3
Carbonic acid,	62·3	71·6
Nitrogen,	14·5	13·1

It has moreover been found, that it is in the red corpuscles that these differences chiefly are seen; hence the idea that they are to be regarded as carriers of oxygen into the system, and of carbonic acid out of it; whether or not we adopt Liebig's theory, that they possess this power by virtue of the *iron* which they contain.

As regards the cause of the *change of colour* in the blood under the influence of respiration, nothing absolute can be stated; though there are many well-established facts. The arterial hue

may be produced in venous blood, by the replacement of carbonic acid by oxygen: the mere abstraction of carbonic acid will not effect it; it requires the exposure to oxygen, or the presence of saline matter. Indeed, Dr. Stevens found that unless there was saline matter present, even oxygen failed to restore the colour;—hence the importance of saline matter to the blood, to insure its due oxygenation.

Scherer, Mulder, and Nasse adopt the view that the difference between the arterial and venous colour is due to *physical* rather than to chemical principles; and they suppose it to depend upon a change in the form of the corpuscles;—that whenever they assume the bi-concave form they will reflect more light, and appear bright red; while in the bi-convex form they refract, and appear dark. These changes in the form of the corpuscles are attributed to the carbonic acid, the saline matter, and chiefly, according to Mulder, to the oxy-proteine produced in respiration, which is supposed to form a coating for each of the corpuscles, and by its contraction to occasion the bi-concave shape. Henle and Schultz have shown that oxygen produces the bi-concave form, and carbonic acid the bi-convex form in the blood-corpuscles out of the body.

The blood also parts with a considerable quantity of water, in the lungs, in the form of vapour. This is apt to be impregnated with some animal matters, and with volatile or odorous substances taken into the blood. No doubt a great part of this water is an exhalation from the extended surfaces of the pulmonary capillaries, through their very delicate membrane; but it is also likely that part of it is formed by the direct union of some of the oxygen absorbed, with the hydrogen of the oily matters of the blood. The total quantity of water thus thrown off will vary (though not so much as the cutaneous transpiration) with the hygrometric state of the atmosphere: it has been estimated at from 16 to 20 ounces in twenty-four hours.

The aeration of the blood may take place, not only by means of the lungs, but also through the skin. This is particularly well seen in the skin of the Batrachia, which is soft and moist. Ex-

periments made on the human subject also prove the same fact; for if a limb be immersed for some hours in an air-tight vessel, containing pure atmospheric air, a sensible quantity of carbonic acid will be observed, which must have escaped through the skin.

Of Asphyxia.—Before dismissing the subject of respiration, it may be proper to note the more prominent points connected with asphyxia. By this term is understood the state of system produced by a suspension of the aerating process. It may be produced in aquatic as well as in air-breathing animals, simply by cutting off the supply of air. Thus, a fish placed in water from which the air has been expelled by boiling, will die as certainly as an animal placed in a vacuum.

There are many causes which may produce deficiency in the aeration of the blood; as 1st, mechanical obstruction to the entrance of air, as seen in hanging, strangling, drowning, choking, or closure of the glottis by œdema;—2d, a want of mechanical power, preventing due movement of the chest, as in violent compression;—3d, a want of oxygen in the air, or the presence of noxious gases in it, as carbonic acid, sulphuretted hydrogen, &c.;—4th, a want of nerve-power in the respiratory ganglion, or failure in the nerves to transmit this power.

The first effect of the non-arterialization of the blood, from any of the above causes, is a stagnation in the capillaries of the lungs. This is due, not to a loss of the contractile force of the heart, for as yet the heart has not been affected, but to the loss of the capillary power, resulting from a want of those chemical changes in them, which are produced in a healthy condition.

The circulation in the pulmonary capillaries is not at first entirely arrested; for the quantity of oxygen already in the lungs partially arterializes the blood, which, in this imperfect condition, is transmitted through the system, and fails to exert its due stimulus especially upon the muscular and nervous tissues. As the air in the lungs continues gradually to grow more deteriorated, the stagnation in the pulmonary capillaries becomes more complete, until finally it is entirely arrested, and the venous blood is backed up in the pulmonary artery, in the right cavities of the heart, and

in the whole venous system. The arteries, on the other hand, are almost completely emptied, through the systemic capillaries not receiving new supplies from the heart.

The nervous and muscular systems lose their sensibility from two causes,—the deficiency of arterial blood, and the venous character of the blood which the arteries may contain. Hence result the irregular movements, and at last an entire cessation of motion, except in the heart, which is the last to stop,—the right side, owing to over distension, which produces a sort of paralysis, the left, from a mere want of its ordinary stimulus—arterial blood.

The time at which asphyxia comes on varies, as before stated, in different animals, and even in different states of the same animal. In the majority of warm-blooded animals, insensibility and a loss of voluntary power come on generally within two minutes after the air has been cut off, though the convulsive struggles may continue some minutes longer. The circulation ceases usually within ten minutes. There are certain animals, as the whale, whose vessels are arranged in large plexuses, by which the proper amount of aeration is maintained without the necessity of very frequent renewal.

In the hybernating animal, the system is reduced to the condition of the cold-blooded animals, which are able to bear a long suspension of the aerating process. The same thing is true also of a person in syncope, where the activity of the functions is already reduced by a failure of the heart's power, and the demand for the respiratory process is, consequently, less. It is probable for this reason, that instances are met with of persons asphyxiated from drowning, who are restored after upwards of a half hour's submersion,—a state of syncope having been brought on at the moment of immersion, either through alarm, or concussion of the brain.

The leading indication in the treatment of asphyxia, is to restore the capillary circulation by the admission of pure air into the lungs. Artificial respiration will often sustain life, provided the action of the heart has not entirely ceased.

Various diseases result from a defective respiration, even where life continues. One of these is the *fatty liver*, in which the fatty matter, which ought to be thrown off by respiration in the form of carbonic acid, is thrown upon this organ, distending its cells. Another disorder, intimately connected with, if not dependent on defective respiration, is *diabetes*, as lately explained by M. Bernard. (*Vide* Part II. *Sugar.*) So also, a deficiency of fibrine, may be produced as a result of an imperfect elaboration from the want of oxygen; hence *scrofula* is so frequently connected with unusual smallness of the chest. Again, we have various venous congestions, as of the face, the liver, the spleen, &c.:—thus, also, the livid colour of the surface in apoplexy, or narcotic poisoning;—also, in typhoid fever, where the cause seems to reside in the nerve-centres of respiration.

SECTION II.

THE CIRCULATION OF THE BLOOD.

The main object of the function of the Circulation is to convey the nutritive fluid to every part of the living organism, so as to place at the disposition of each living molecule the materials necessary for its growth or renovation. In this manner, the circulation is subservient to the process of nutrition. But as every act of life is accompanied by a necessary disintegration or waste of structure, through the decomposing agency of the oxygen introduced in the act of respiration, it becomes another very important purpose of the circulation, to carry out of the system these effete materials by bringing them within the influence of the various secreting cells; and also of conveying into the system the supply of oxygen necessary for the action of the nervous and muscular tissues, as well as for the incessant chemical changes just alluded to. Still, a third office of the circulation is to eliminate from the economy the carbonic acid, which chiefly results from the pro-

cess of calorification, the retention of which would speedily prove fatal. Hence, it is found that the energy of the respiration bears a close relation to the activity of the circulation.

Plants exhibit a circulation as well as animals. In both, the functions of nutrition and secretion are essentially identical; and in both, the circulation of the organizable material, upon which these functions depend, is essentially the same. Vegetables, it is true, possess no propelling organ, or heart; but neither is this found in the lower animals. In the higher plants, the circulation consists of a double current,—an *ascending* one conveying the crude sap, derived from the soil, and due, partly, to the endosmotic force residing in the spongioles of the roots, and partly to the exhalation of fluid from the growing buds and leaves,—and a *descending* one, conveying the elaborated sap, which more especially resembles the blood of animals, having received an additional supply of solid matter by the decomposition of the carbonic acid of the air through the cell-action of the green surfaces, and under the agency of the sun's light. It is the circulation of this elaborated sap that particularly resembles the capillary circulation of the higher animals, as will be hereafter explained,—neither of them being dependent upon a central organ, but both being due to certain affinities existing between the molecules and the circulating material.

Certain vegetables exhibit a kind of movement in their organic cells, which is sometimes regarded as a species of circulation; it has received the name of *rotation*. It is best seen in the cara, and other aquatic plants, which consist of a number of separate cells, on the walls of which are arranged a number of green bodies —probably chlorophyll granules—in a spiral manner. The movement of the liquid of each distinct cell continues so long as the granules remain adherent to the cell-walls; but if they be detached, they continue to rotate upon their own axis. No satisfactory explanation of this movement has ever been afforded; it has been vaguely attributed to electricity. Schwann has observed a similar movement in the pigmentum nigrum of the eye, and in the ger-

minal membrane of the egg. It may possibly be a property of the organic cells of animals.

Varieties in the Circulation of Animals.—In order properly to understand the nature and objects of this function, it should be studied in the very lowest animals, and in the embryonic condition of the higher ones. It is a law invariably observed in the development of the organism, that the parts which are most essential are those which are first formed, the others being progressively superadded for the perfection of the function to be performed. This law is very distinctly observed in the development of the circulatory apparatus. In the lowest order of animals and in the embryonic condition of the higher, there are no distinct vessels, but each part, or each individual cell, has the power of directly absorbing the nutritious matter either from without, or from their digestive cavity.

Vessels are first met with in the entozoa and in the acalephæ or jelly-fish. These vessels take up the nutritive fluid from the digestive cavity, upon the walls of which they spread out, like the roots of plants in the soil. They then unite in trunks conveying the nutriment to every part; these trunks afterwards subdivide into smaller or capillary branches, some of which going to the surface are subservient to aeration. The fluid is then collected by other trunks, which carry it back to the point from which it started. The movement here is analogous to that of the elaborated sap in vegetables, being due to the varying affinities existing between the nutritive fluid, and the parts through which it circulates. This is very much the condition of the human embryo, when vessels are first developed in it; the movement is towards the central spot, and is essentially capillary. In the next higher class of animals we find provision made for a more vigorous circulation, in the endowment of the chief vessel with a contractile power. This is the case with the worm, in which the dorsal vessel may be seen in a constant state of alternate contraction and expansion. In the centipede and in insects, this dorsal vessel is divided into separate segments, by transverse partitions containing valves. Each of these cavities acts, to a certain extent, as a heart

for a correspondent portion of the body, but they all participate in the general circulation. Sometimes several dorsal vessels may be seen at each side, uniting in front to form a single trunk, which runs backwards at the lower surface of the body, distributing the blood by lateral branches. The chief cause of the circulation here, is evidently not the contraction of the vessels, but the forces developed during the progress of the fluid, as in vegetables.

In insects, the circulation is much less vigorous than in the other articulata; though it might have been expected, from the great rapidity and energy of their movements, that there would have been a corresponding activity of the circulation, for the purpose of affording a due supply of oxygen. This is provided for in another manner, the air being conveyed to the tissues, not through the blood, but through ramifications of the trachea and air-tubes, which penetrate to all parts of the body.

In the mollusca, there is a distinct heart with muscular walls, having two separate cavities, an auricle and ventricle. The ventricle sends the blood through the body in general; this is collected again, and transmitted through the respiratory organs, where it becomes aerated, either from the surrounding water, or from the atmosphere; and from these it is returned to the auricle, to be again sent through the system; hence the heart is merely systemic. In some of the lowest mollusks there is observed a constant retrograde motion of the blood, after it has proceeded a certain distance; this appears to arise from a deficiency in the contractile power of the heart.

In fishes, the heart belongs to the respiratory system, since it is placed at the commencement of this system. It consists of one auricle, and one ventricle; the auricle receives the venous blood and transmits it to the ventricle, which sends it through the branchial arteries of the gills, there to be aerated by the action of the water: thence it is returned by the branchial veins to the aorta, which transmits it throughout the system. From the systemic capillaries, the blood from the anterior part of the body and head, proceeds immediately to the vena cava; but the blood of the posterior portion of the body and of the abdominal viscera is trans-

mitted to the liver and kidneys, where they minutely ramify so as to form the portal system, whence they collect again to join the vena cava, which empties into the auricle. Hence, in fishes, we perceive that *all* the blood is transmitted through the gills for aeration.

In reptiles, whose motions are dull and sluggish, only part of the blood goes to the organs of respiration; hence, in them the heart contains two auricles and one ventricle. One auricle receives purely venous blood from the systemic capillaries, through the vena cava; the other receives purely aerated blood from the pulmonary capillaries, through the pulmonary vein. Both auricles discharge into one common ventricle, which consequently transmits blood of a mixed character to the various parts of the system, but which is sufficient to keep up the sluggish motions of these animals. The frog, in its early or tadpole state, breathes like a fish, through the gills; but in proportion as it becomes developed into its more perfect condition, does the blood begin to be sent to the lungs; and at full maturity the gills are no longer serviceable. In some of the higher reptiles, as the crocodile, the single ventricle is arranged so as to transmit perfectly aerated blood to the head and anterior extremities, whilst mixed blood is sent to the posterior parts of the body.

In birds and mammalia, the circulation is distinguished by its complete double character. The heart, in them, may be considered as consisting of two distinct halves,—one a *systemic* heart resembling that of reptiles; the other a *respiratory* heart, resembling that of fishes, each of which contains an auricle and a ventricle; consequently in such the circulation is double; one portion, the *systemic,* being designed for the general system; the other, the *pulmonic,* for the lungs. There is no direct communication between the two halves, at least in the adult, though their walls are united for economy of space. In such animals, every portion of venous blood becomes aerated in the lungs, before it is returned again to the heart for distribution to the system. A portion of venous blood, that which has traversed the walls of the intestines, is not returned directly into the vena cava, but is collected into a

large venous trunk called *vena portæ*, which ramifies minutely like an artery through the liver, where the bile is secreted; it is then collected again into the hepatic vein, to be finally emptied into the vena cava.

The heart is formed, last of all, in the vascular system; and is only developed in its perfect state in the highest animals and in man. Its muscular power is greater in proportion to the extent of the circulation; hence it is greater in warm-blooded animals, in whom it appears to be the chief agent in the circulation. Some contend for its *exclusive* agency in the propulsion of the blood: this question will be examined when treating of the Capillaries.

In analyzing the different parts of the Circulation, they may naturally be considered under two divisions, the mechanical or physical portion, consisting of the heart, arteries, and veins,—a true hydraulic apparatus, and the capillaries, or irrigating system. In the former, there is a considerable display of the dynamic force; in the latter, the molecular forces are chiefly concerned.

Of the Heart.—The heart is a hollow muscle, endowed with great contractile power, dependent upon an inherent *irritability*, or, "capability of contracting and dilating alternately under an appropriate stimulus." Its movements differ from those of other muscles in this, that, while in them the individual fibres are in a state of alternate contraction and relaxation, when the whole muscle is in an active condition, in the heart the whole of the fibres of each division contract and relax *together*. In its connexion with the circulation it may be regarded simply in the light of a mechanical instrument—a living forcing-pump, differing, however, from all artificial machines in this, that its power is not extraneous, but resides in its own walls, and that it is capable of self-reparation; this constant renewal of its own wasted materials is, in fact, its only *vital* action. In all the higher animals, the heart consists of four cavities, two auricles, and two ventricles. The auricle and ventricle of each side communicate with each other by means of valves which are attached to the fleshy columns of the heart by means of the chordæ tendinæ. The walls of the four cavities are of different thickness. That of the left ventricle is

greatest, because it is obliged to exert a greater contractile force; the average is about four and a half lines; it is greatest near the middle. The average thickness of the right ventricle is one and a half lines, being greatest at the base. The left auricle is somewhat thicker than the right, being, according to Bouillaud, one and a half lines. The capacity of the four cavities is very nearly the same, being about two ounces. The ventricles are a little the largest.

The usual stimulus of the heart's action is the *blood*, as is shown by removing the brain and spinal marrow, and keeping up artificial respiration, which maintains the circulation in the lungs. When the supply of aerated blood entirely ceases, the action of the heart stops; and this takes place much sooner in warm-blooded than in cold-blooded animals; thus, the heart of a frog will continue pulsating many hours after its removal from the body, and that of the turtle even after it has been cut into pieces. It is not, however, the mere contact of the air which causes the contractions to continue, when the heart is emptied of blood, since it will continue when a frog's heart is placed under the exhausted receiver of an air-pump. Its movements have been supposed to depend upon *nervous* influence. This is not the case, since they occur in acephalous monsters, and continue even after the brain and spinal marrow are destroyed, provided the destruction be not sudden. Again, they have been referred to the sympathetic system; but the facts above stated, showing that the heart's action will continue when taken out of the body, are sufficient to prove that no nervous influence is essential. Still, it is very much *influenced* by nervous action: thus Valentin found that when the heart had stopped pulsating, its action might be re-excited by irritating the spinal accessory nerve, or the first four cervical nerve. Irritation of the par vagum will excite it to increased action; but *both* trunks may be divided, and very little disturbance ensue. The heart is excited more, perhaps, through the ganglionic system of nerves—as by irritation of the cervical ganglia, particularly the first; and a case is recorded of very great diminution in its pulsations, causing extreme anxiety, produced by an enlarged bronchial

gland pressing upon the cardiac nerves. It is believed that some cases of angina pectoris may depend on a lesion of the cardiac plexus. It is probably through the sympathetic nerve that the heart is so much influenced by the *emotions.*

Any sudden or violent impression upon the nervous system may suspend, or even entirely stop, the heart's action, although there be no loss of nervous substance,—thus concussion of the brain, or a violent blow upon the epigastrium, which frequently causes instant death from the shock upon the large plexus of ganglionic nerves distributed over the viscera. Violent impressions upon other nervous expansions may also produce a great loss of the heart's energy; in this way a severe superficial burn may cause such a depression, particularly in cases of children, as shall prevent a reaction, and produce death.

The contraction of the two ventricles, or their *systole,* is perfectly synchronous; so is that of the two auricles: but the systole of the auricles is synchronous with the *diastole* of the ventricles, or their dilatation. The regular succession of the auricular and ventricular contractions in the natural state may be owing to the fact that the contraction of the auricle forces the blood into the ventricle, which is instantly excited to contract by the presence of the blood—its appropriate stimulus; and, while the ventricle is contracting, the auricle, now free to dilate, is filled with blood from the veins; and the stimulus of this blood causes contraction of the auricle, just when the ventricle has ceased contracting, and is ready to receive the contents of the auricle. The *duration* of the systole is double that of the diastole. There is hardly any pause between the different acts of the heart when they are vigorously performed. The contraction of the auricles commences at the insertion of their veins, and is thence extended throughout. The ventricular systole propels the blood through the aorta and pulmonary artery; and it also corresponds with the *pulse,* and, as is usually supposed, with the *impulse* of the heart against the chest (between the cartilages of the fifth and sixth ribs). This impulse is produced by the peculiar manner in which the systole takes place; though the ventricle contracts in every direction, its

shortening is most obvious; and, owing to the spiral arrangement of its fibres, its apex is made to describe a spiral movement from right to left, and from behind forward. The *diastole* is not a mere passive movement, as is shown by the great force it is capable of overcoming. The diastole consists of two movements, —the fall of the heart backwards, and its sudden dilatation in every direction. Between these two movements there is a brief interval of repose.

These movements of the heart are accompanied by certain sounds, called the *sounds of the heart*, which are valuable as diagnostic signs; they are named the *first* and *second* sounds. The first is generally described as being produced by the ventricular systole, and is synchronous with the pulse; it is dull and prolonged. The second is short and sharp, and follows immediately after the first; and it must be caused during the first stage of the ventricular diastole. It is followed by a brief interval of repose, during which the second part of the ventricular diastole, and the auricular systole occur. If the interval between two beats of the heart be divided into four parts, two will be occupied by the first sound; one by the second; and one by the interval of repose.

The *cause* of the sounds has given rise to much difference of opinion, and is not yet definitely settled. Laennec attributed them to the alternate contraction of the ventricles and auricles;—this will not explain it. The first sound is of a complex nature, and depends upon several causes:—1st. The impulse against the thorax, since when this impulse is prevented the sound is fainter; but it is not exclusively due to this, since the sound has been heard when the heart was outside of the body. Some authorities, however, maintain that the *impulse* is produced by the diastole, and not by the systole. 2d. The rush of blood through the orifices of the aorta and pulmonary artery; this is proved by the occurrence of any obstruction at these orifices, by which both the intensity and prolonged character of the sound are increased. 3d. The friction of the muscular fibres,—since every muscle produces some sound in contracting. 4th. The movement of the blood over the rough, internal surface of the heart. The second sound is more

simple, being due to the click produced by the sudden filling out and closure of the semilunar valves of the aorta and pulmonary artery, just as the diastole of the ventricle is commencing, and the blood has a tendency to regurgitate into it again. There is no difference of opinion upon this point. If one of the semilunar valves be hooked back, no sound is heard; and if their complete closure be prevented by disease, the sound is either lost, or very much diminished; hence its value in diagnosis. The reflux of blood in this case is indicated by a *prolonged* second sound, similar to the first. The second sound can be traced some distance along the aorta.

The movements of the auriculo-ventricular valves (tricuspid and mitral) commonly occasion no sound, because their closure is more gradual than that of the semilunar valves,—as they are restrained by the chordæ tendineæ. But when these valves are diseased, they may give rise to morbid sounds termed *murmurs*. The columnæ carneæ merely give stability to the margins of the valves: they exert no active influence.

In health, no sound is produced by the opposite surfaces of the pericardium rubbing together, as they are moistened by serum; but in inflammation of this membrane, when it becomes dry or roughened, a *friction* sound is heard.

The tricuspid valve does not close so completely as the mitral; hence there is a partial retrograde motion into the right auricle, which accounts for the venous pulse seen in the jugular veins of some persons. It is a wise provision, intended to guard against over-distension, which is very apt to occur in congestion of the pulmonary vessels, and in great exertions. Hence, in asphyxia, in which this pulmonary congestion always occurs, bleeding from the jugular vein may prove of great benefit, by relieving the over-distended right auricle.

The *dynamic force* of the heart may be estimated by the usual mode of first ascertaining the actual resistance to be overcome at each contraction, and then the number of such efforts that are made within a given time. The quantity of blood propelled at each contraction of the ventricles is nearly two ounces, since they

do not completely empty themselves. Now, taking the whole amount of the blood to be one-fifth of the weight of the body, it will amount to twenty-eight pounds in a person weighing one hundred and forty pounds. Allowing seventy-five pulsations to the minute, we shall have 150 ounces, or 9 pounds 6 ounces passing through the heart in each minute; and, consequently, about three minutes would be required for the whole of the blood to pass through the heart, on the supposition that the circulation was governed entirely by the heart's action. At this rate, the heart must expend an amount of dynamic force in twenty-four hours sufficient to overcome a mechanical resistance of 13,440 pounds. But actual experiment shows a much more rapid circulation than this; for a saline solution injected into the jugular vein of a horse was detected in the carotid artery of the opposite side in twenty seconds. A saline solution injected into the jugular vein of another horse, was detected in the veins of the lower extremity in a little over twenty seconds. Hence we must conclude that the *rapidity* of the circulation is due to some other than the heart's action. Some have ascribed it to the rapid *diffusibility* throughout the current of blood, of the substance injected.

The actual propelling force of the heart was estimated by Hales by inserting a long pipe into the carotid of a horse; he found the column would sometimes rise as high as ten feet. By comparative experiments, he estimated the force of the human heart to be capable of supporting a column, in the aorta, 7½ feet high, the weight of which would be 4½ pounds, upon a surface equal to the area of the aorta. Another method was adopted by Poisseuille—by means of an instrument called a hæmadynamometer, which consisted of a bent tube containing mercury, one leg of which was horizontal; the horizontal portion being inserted into the artery, the propulsive force was measured by the height to which the mercury rose in the tube. The result very nearly corresponded with Hales',—being 4⅓ pounds. The true measure of this force, then, is estimated by multiplying the pressure in the aorta, into the surface of a plane passing through the base and apex of the left ventricle; by which calculation it is found to be thirteen

pounds, for the contractile force of the whole ventricle. It is probable, however, that the whole of this enormous force is not dependent upon the nerve-centres, since, as we have seen, the heart can act independently of nervous influence. Still, there do occur cases of great feebleness of the heart's action, accompanied with a disposition to syncope on the slightest exertion, which are clearly traceable to a deficient action of the nerve-centres supplying the heart. A feeble frequent pulse indicates the heart's failure.

Action of the Arteries.—The arteries are simple hydraulic tubes for transmitting the blood to the various parts of the body. The ancients supposed them to be air-tubes to convey air into the interior of the body. They are composed of three coats—an external, or cellular, which is the strongest, a middle or elastic, and an internal or serous. The blood flows into the arteries in successive jets, owing to the contractions of the heart; and this interrupted character of the flow would continue, if it were not equalized by these vessels. Their middle or fibrous coat consists partly of a yellow elastic tissue, and partly of a non-striated muscular fibre. The elastic tissue predominates in the larger arteries; the muscular in the smaller. The elasticity of the arteries is the chief cause why the blood is propelled in a continuous stream. Thus, if a forcing-pump be adjusted to an elastic tube, although the fluid is forced in by successive jets, it will issue from the other end in a continuous stream. The elasticity of the arteries is not absolutely indispensable; since it is lost in ossification of the vessels in old people; but in such persons, very slight causes may produce death. Under the impulse of the heart, the arteries dilate both in their length and breadth; the increase in the length is greatest, which causes the vessel to be lifted up from its seat. The transmission of the pulse-wave through the whole system is not instantaneous, but takes place in an appreciable time. The pulsation of the large arteries near the heart, is synchronous with the systole of the ventricle; but that of the smaller and distant arteries is later, varying with the distance, and amounting sometimes to the one-sixth of a second.

The muscular contractility of arteries has often been denied;

numerous experiments, however, prove its existence—such as their contraction under the application of stimuli to their walls; the fact, that when an artery is dilated with blood thrown into it by the heart, it reacts with a force *greater* than the impulse; also, if a portion of an artery from an animal recently dead, in which the contractile power is yet preserved, and a similar portion from an animal that has been dead some days, and in which the *elasticity* only remains, be distended with equal force, the reaction of the former is much greater than the latter. The object of this contractile power of the artery is to assist the heart in the propulsion of the blood. It may also serve to make up for the loss of power occasioned by the friction of the blood against the sides of the vessels. If an artery be twisted, or violently torn, hemorrhage is usually prevented—probably by its contractility being destroyed, in consequence of the injury done to the coats of the vessel preventing the subsequent expansion. The power which the arteries have of adapting themselves to the quantity of blood to be transmitted seems to be due to their muscular contractility. This is seen in the case of the uterine and mammary arteries during pregnancy and lactation; also in diseases attended with increased action of particular organs. In such cases it cannot be the *vis â tergo* of the heart that causes the enlargement, since this would necessarily affect all alike; it must be due to a power inherent in themselves; and it is probable that the sympathetic nerve controls this power, and distributes the blood according to the wants of the system.

The relative capacity of the arteries is very nearly the same in every part of the body; that is, if a section were made through all the systemic arteries at any given point, their united areas would be equal to that of the aorta, although the diameters of the branches, at each subdivision, together exceed that of the trunk. But the calibre of a tube is estimated by its *area*, and not by its diameter; and the areas of circles are as the squares of their diameters. Hence the comparison must be made between the *square of the diameter* of the trunk and the *sum of the squares* of those branches. Thus an artery, whose diameter is 7, may subdivide into two branches, each of which may have a diameter of about 5,

and yet their *areas* be alike; for the square of 7 is 49, and twice the square of 5 is 50; and so on with other examples. The *pressure* is the same upon every part of the arterial system.

The object of the frequent *anastomoses* between the arteries is to insure the continuance of the circulation, in case of the main trunk becoming obstructed. This is seen in the operation of tying an artery in aneurism, when the supply of blood, which was at first cut off, is very soon restored through the collateral branches, which become very much enlarged; while the main trunk is usually found to have become quite impervious above the ligature up to the first anastomosing branch.

The *pulse* is produced by the propagation of the ventricular contraction through the arteries by means of the wave of the blood. It is not perfectly synchronous in every part of the body. If the column of blood be interrupted by any obstacle, as by an aneurismal tumour, or if the blood does not completely fill up the calibre of the vessel, the pulse is not fully developed; there must be full *tension* of the coats of the vessel as well as a due *tonicity*. If the tube were not elastic, the mere contraction of the heart could produce no pulse; and if it yielded too much to the distending force, this force would be expended upon the sides of the vessel, and the movement of the blood would be arrested, or would proceed very slowly. So again, there must be a certain resistance in the capillary vessels, since, if this be taken off, the arteries empty themselves, and the pulse ceases. The pulse is liable to great variations within the limits of health. The chief influences are the following:—*Age.*—In the fœtus* it averages from 140 to 150 beats in a minute; at birth it is about 130; at one year, 115 to 120; at 7 years, 85 to 90; at puberty, 80 to 85; at manhood, 70 to 75. It gradually declines to old age, when it is from 40 to 60. *Sex.*—In females the pulse is usually from 10 to 15 beats more frequent than in men. It is also more liable to disturbance. *Temperature.*—Increase of temperature produces an increase of the frequency of the pulse. *Muscular exertion* always accelerates

* Dr. Valleix has lately stated that at birth the pulse is less frequent than at six months.

the pulse. Posture exhibits the effects of long-continued muscular exertion upon the pulse: thus, in the standing posture, it will beat 7 to 10 strokes faster than in the sitting position, and 4 or 5 strokes faster in the sitting than in the recumbent posture. Hence, the patient's pulse should never be examined while standing, particularly if under the effects of digitalis, which powerfully depresses the action of the heart. The difference in position is most striking in very feeble persons. The pulse is also more frequent in tall and thin persons, than in those who are short and fat. The *mental emotions* produce a powerful influence on the pulse, particularly in females. It is familiarly witnessed in the effects produced by the mere visit of the physician upon the pulse of nervous patients of either sex. Hence the rule always to wait a little while before ascertaining the state of the pulse. The *intellectual* operations do not appear very sensibly to affect the pulse, unless a state of feverishness be induced. During digestion the pulse is rather quickened; it is rather more frequent in the morning than in the evening.

The pulse is either increased in frequency in enfeebled health, or is very easily accelerated: on the contrary, it becomes slow and full as the energy of the system increases. Hence we have an invariable rule for the administration of tonics and stimulants

The pulse is not to be regarded as an index of the condition of a *single* organ, but of a variety of organs, as, 1st. Of the heart, as respects its force, regularity, slowness, &c. 2d. Of the aortic valves; disease of them may be suspected when there is a strong impulse of the heart attended with a feeble pulse, or if the pulse is very irregular, while the action of the heart is regular. 3d. Of the quality of the blood;—when it is thin and watery, the pulse is full and gaseous and easily compressible: such a pulse is easily excited. 4th. Of the condition of the arteries;—the pulse is soft, when their contractile power, or tonicity is enfeebled. 5th. Of the state of the capillary circulation;—thus in an inflammatory or congestive stasis in the capillaries, we have resistance, causing a distension of the arteries and a more bounding pulse; but when their vital activity is diminished, we have a more feeble pulse;

and when they are nearly emptied, the pulse almost ceases to beat. 6th. Of the condition of the nervous system,—as noticed above.

Action of the Veins.—The veins are formed by a reunion of the small vessels in the capillary rete; they carry the blood back to the heart. The great mass of the blood enters the venous system from the capillaries; but a portion of it comes immediately from the arteries, by means of directly communicating channels. The systemic veins circulate black or venous blood; the pulmonary veins, arterial blood.

The structure of the veins is very similar to that of the arteries, but their middle coat possesses less contractile power. M. Bernard has lately announced the discovery of longitudinal muscular fibres in the ascending vena cava and hepatic vein, the function of which, according to him, is to aid in the hepatico-renal circulation. With this exception, the veins are believed to be destitute of muscularity. The whole capacity of the venous system is estimated at two or three times that of the arterial; consequently the rate of movement in them must be proportionally slower, the velocity of the circulation being inversely as the calibre of the vessel. The veins are distinguished by their *valves*, which are formed of duplications of their lining membrane, and intended to prevent a reflex movement of the blood. There are no valves, however, in the vena portæ.

The circulation in the veins depends chiefly upon the contractile force of the heart and arteries. Experiments show that a power less than that of the heart is sufficient to drive the blood through the veins. Other causes, however, contribute to the circulation, as 1st. The movement of inspiration, which produces a partial vacuum in the chest, and thereby favours the current of blood towards the heart, causing the respiratory pulse seen in the veins of the neck in thin persons. This is also proved by the experiment of inserting a tube into the jugular vein of an animal, the lower end being dipped in water; at each inspiration, the water is drawn up into the tube. 2d. Muscular movements;—each movement will cause some of the veins to be compressed; and since the blood is prevented by the valves from going backward,

it must be propelled towards the heart. This is familiarly witnessed in venesection, every movement of the hand increasing the flow of blood from the orifice. Hence, sudden and violent exertion is very dangerous in cardiac diseases, in consequence of the impetus of the blood. 3d. The partial regurgitation from the ventricle into the auricle, during the ventricular systole. This occurs whenever there is an over-distension of the heart, resulting from some obstruction to the circulation through the lungs, as in chronic dyspnœa, &c. *Gravity* appears to have much more effect upon the venous, than upon the arterial circulation, chiefly on account of the less amount of tonicity in the former, as may be proved by experiment out of the body. We can thus understand the cause of œdema arising in relaxed debilitated states of the system, where, the venous circulation being particularly influenced by gravity, the watery parts of the blood transude through the vessels. The *varicose* veins of the leg are often attributable to a similar relaxed condition. The influence of gravity is also seen in the beneficial effects produced by proper position upon an inflamed limb, so as to drain it of blood. As before mentioned, the veins have the power of absorption.

Action of the Capillaries.—The capillaries are the minute vessels intermediate between the arteries and veins. They may be regarded as the most important part of the whole circulating system, since it is in the capillary region that all the forces of life are displayed—the chemical, dynamical, and vital functions; here alone is nutrition accomplished; and here also occur all the pathological phenomena resulting in disease. Two sets of capillary vessels exist, one consisting of the gradually diminishing terminations of the arteries and of the gradually increasing commencements of the veins; the other set comprising the intermediate fine network or *rete*, of uniform size, and of so small a calibre as only to admit a single row of blood-corpuscles. The large capillaries will admit two or three rows of corpuscles, and may be observed to be undergoing a constant variation in size, by contraction and dilatation. Though extremely delicate in their texture they have distinct walls. Henle's notion that they possess muscularity is unsupported by any evidence.

The form of the capillary rete is different for each organ of the body, so that a portion of the minutely injected capillaries would suffice to enable the anatomist to determine from what structure it had been taken;—thus, there is one sort for the muscle, another for a mucous membrane, a third for a follicular mucous membrane, a fourth for a nervous centre, a fifth for the papillæ, &c. As respects the question whether there are capillaries which circulate only *white* blood, as in the white tissues,—the probability is that they are only the common capillaries in a state of extreme contraction, circulating but a single file of corpuscles, which, under the microscope, appear nearly colourless;—hence the white tissues may appear to be destitute of red blood, from the small number of capillaries which they contain.

The phenomena of the capillary circulation are best studied in transparent tissues, as the web of a frog's foot, or still better in a partially incubated egg. Under the microscope two distinct currents may be observed, one, the central—in which the red corpuscles move rapidly forward; the other moving much more slowly, along the sides of the vessel, consisting of the liquor sanguinis, in which a few white corpuscles may be noticed. It is from this latter layer, in contact with the sides of the vessel, that nutrition is effected,—the plasma passing out by endosmose under the vital affinity exerted by the molecules of the organs. The great object of the capillary circulation would seem to be to bring the blood in a finely divided state in relation with the minutest parts of the organs, so as to present the conditions most favourable for the functions of nutrition, secretion, and aeration of the blood;—thus, for example, in the lungs, by the extreme minuteness of the capillary rete, a very considerable surface is brought into relation with the inspired air, and thereby a large amount of oxygen taken in, and carbonic acid given out at each movement of respiration. The same is true of the other functions.

The movement of the blood in the capillaries depends upon several causes. In the first place the contractile force of the heart extends through them; for when this becomes weak or irregular, a considerable change is manifested in the capillary circulation.

On the other hand, the capillaries evince an independent power of greatly controlling the circulation of the blood in them. This is manifested by observing the capillary circulation in a transparent tissue—as the web of a frog's foot, when constant changes may be noticed; some tubes may be seen enlarging so as to admit several files of corpuscles, which before were only large enough for a single file; and others will become apparently obliterated, from their extreme contraction. Again, the velocity of the blood in the capillaries is by no means uniform, even where there is no interruption to the heart's action; for frequently an entire stagnation will occur, and even a change in the direction of the current. In the lowest animals, as well as in vegetables, we know that the circulation is maintained in the minute vessels, without the aid of a heart, and indeed entirely independent of any *vis à tergo*, but by some power closely connected with the state of their nutritive and secretive processes. The same is true as we ascend the animal scale, though the *capillary power* becomes modified very much by the force of the heart. Still, in cold-blooded animals, the movement of the blood in the capillaries has often been seen after complete excision of the heart; and although the same experiment cannot be performed on warm-blooded animals, in consequence of the severity of the operation, it may be proved to occur in them in other ways. Thus, after a natural death, the arteries are found to have emptied themselves completely in the course of a few hours: the mere *tonicity* of the vessels is not sufficient to account for this, hence the inference that the capillary circulation must have continued. Further, it is known that a real secretion continues after death, which we know would be impossible without the capillary circulation. In the development of the vascular system in the embryo, the first movement of the blood is always *towards*, instead of *from* the centre.

The true principles which regulate the capillary circulation are believed to be essentially the same as those which govern the circulation of the sap in vegetables, and which have been explained by Prof. Draper. If two liquids be made to communicate with each other through a capillary tube, for which they have an un-

equal affinity, a movement will ensue; the liquid which has the strongest affinity being absorbed most rapidly into the tube, driving the other before it. The same is true if instead of a single tube, a network of tubes, or a porous substance, be used; the liquid with which it may be saturated will, as in the former case, be displaced by another for which it has a greater affinity. Now to apply this to the circulation of the sap in vegetables, or of the blood in the capillaries: the different molecules of the structure have an affinity for different materials in the circulating fluid; such materials are appropriated to those particular parts, thus, the different cells, by virtue of their selecting power, attract the peculiar matters of their growth or secretion; and the circulating fluid having given up these materials, has no longer the same affinity for these particular parts which it had before, and it is consequently driven from them by the superior attraction then exerted by a new portion of fluid, which is destined, in like manner, to be replaced by another portion, and so on. For example, the blood, having just been charged with oxygen in the lungs, and become arterial, has a greater affinity for all the tissues through which it circulates, than venous blood, which has already parted with its oxygen and become charged with carbonic acid. Consequently, upon the principle just mentioned, the arterial blood entering the capillaries on one side, must drive out on the other the blood which has become venous. In the capillaries of the lungs, on the other hand, we have opposite affinities at work. Here the attraction is between the venous blood and the air, from which results the interchange between them of oxygen and carbonic acid; but when the blood has thus become arterialized, the same attraction no longer existing, it is driven onwards by the venous blood behind it. But suppose the supply of oxygen to be cut off from the lungs, so that the blood is no longer aerated,—then, the attraction no longer existing between the venous blood and the pulmonary capillaries, there is nothing to push it forward through the pulmonary veins into the left side of the heart; hence a *stasis* takes place in the lungs, producing the phenomena of asphyxia.

Thus we are enabled to understand how the rapidity of the cir-

culation in a part will depend upon the *activity of the functional changes* going on in it, whilst the general circulation remains unaltered. For when the nutrition of a part is increased, or when it is stimulated by exercise, a larger amount of blood must pass through it in a given time, in consequence of the affinities being stronger, and more rapidly satisfied; and this may occur without any enlargement of the calibre, although the arteries which supply the part soon increase in size, in order to supply the increased demand. This is well illustrated in the development of the testes at puberty, and of the mammary gland at the period of lactation. From this well-known fact, we have the aphorism "ubi stimulus ibi fluxus." Such a condition is known as *active congestion*, or *determination of blood*, and is dependent upon an undue functional activity of the part. This state is generally the precursor of inflammation; but it differs from it in not consisting in any alterations in the function, but only an exaltation. It is frequently observed in persons of very active minds, when the function of the brain is unduly tasked; the excess of blood sent to the head, is seen in the suffused countenance, pulsation of the carotids, together with the coldness of the lower extremities.

If the above explanation of the cause of the capillary circulation be correct, it is evident that all the theories of inflammation which are based upon any changes in these vessels as its cause must be erroneous. Neither their contraction nor dilatation—whether of an active or passive character—can be regarded as the true *cause* of inflammation: this must rather be sought for in the region beyond the capillaries, that is, in the increased activity of the molecular attractions, demanding an increased supply of blood.

Another opposite condition of the capillaries, is also met with, termed *passive congestion*, in which the functional energy is deficient, and the circulation through the part is consequently retarded. This condition, as well as the preceding, predisposes to inflammation, though in a different mode. Such a congestion is relieved by anything which promotes the action of the part: thus, congestion of the liver is removed by remedies which increase its functional activity, as mercury.

Besides the elective attraction exerted by the living molecules upon the circulating plasma, which may be considered the main cause of the capillary circulation, other subsidiary forces are probably concerned; thus the constant endosmose through their walls would tend to produce a partial vacuum: this would of course exert a *vis à fronte* influence. Some attribute it to electric power, the notion being that in health the vessels and the contained blood are in the same electrical condition, and consequently repel each other, whilst in inflammation their electrical states are opposite, and hence the attraction observed between the corpuscles and the sides of the vessels. This, however, is entirely speculative.

The influence exerted by the nervous system over the capillaries, though not essential, is nevertheless very manifest—especially that part through which the emotions act. This is familiarly seen in the act of *blushing*, which depends upon a sudden enlargement of the capillaries of the face, under the influence of some emotion. So also the opposite state of *pallor*, which depends upon a sudden contraction of the same capillaries under the influence of a strong emotion, as fear. The same thing is also seen in certain glands, as the *mammary*, in which the amount of the secretion is increased through the increased quantity of blood sent to the parts. In this manner "the draught," as it is termed by nurses, is occasioned by the emotion excited by the sight, or even by the thought of the child. It is witnessed also in the salivary and lachrymal secretions. The *quality* of these secretions, which is also altered, as well as their amount, probably depends upon some changes produced in the blood itself through the agency of the nervous system. Although the capillary circulation, as we have seen, occurs independently of the nervous system, still, as in the case of the arteries, any sudden or violent impression upon the great nervous centres, will bring it to an immediate stand.

In connexion with the function of the Circulation, it will be appropriate to describe the *circulating fluids*—the Chyle, the Lymph, and the Blood.

SECTION III.

THE CIRCULATING FLUIDS.

THE circulating fluids consist of the *chyle*, the *lymph*, and the *blood*. These will now be treated of in their order.

I. THE CHYLE.—This name is applied to the milky fluid found in the lacteals, and resulting from digestion. It was formerly the opinion of physiologists that the chyle was composed out of *all* the digestible food received into the stomach, where, having undergone the process of digestion, it passed down into the duodenum, in which a separation took place between the nutritious and unnutritious portions; the former were believed to be absorbed as chyle by the lacteals, while the latter passed on through the intestines as excrementitious. The present doctrine, chiefly based upon Bernard's discovery of the office of the pancreatic juice, is that the chyle is composed almost exclusively of the oleaginous matters of the food which have been rendered absorbable by the lacteals through the agency of the pancreatic secretion; the influence of the latter being to *emulsionate* the fatty matters and thus render them capable of passing through the walls of the lacteals. It cannot, however, be positively affirmed that all the oily products of digestion pass into the lacteals, since Matteucci has shown that an oily emulsion will pass through animal membranes to an alkaline fluid on the opposite side; hence it is not impossible that the blood-vessels may be concerned in the absorption of fat, by this method of endosmose.

The lacteals, commencing on the surface of the small intestines, run together on their walls to form larger trunks; these converge, and unite with each other on the mesentery, after which they pass onwards through the mesenteric glands, to terminate in the thoracic duct. The *mesenteric glands* do not correspond in structure with the proper glands, being simply composed of a convolution of lacteal trunks somewhat dilated and fully supplied with blood-vessels, which, however, do not communicate with the interior of the lacteals.

In its passage through the lacteals the chyle undergoes conside-

rable changes. At the commencement it consists, as we have seen, almost exclusively of an emulsion of oily materials. By the microscope, at this stage it exhibits the presence of a great number of very minute particles, termed by Mr. Gulliver the *molecular base.* These molecules are nothing more than the minute particles of oil covered over with an albuminous coating. Their diameter is the 1-36,000th to 1-24,000th of an inch. They abound most in rich opaque chyle, and are completely soluble in ether,—a proof of their fatty composition. That no chemical change has been undergone by the oily matters, is proved by an experiment of feeding dogs for some time exclusively on the oil of sweet almonds; on killing the animals, the oil was detected unchanged in the stomach, the lacteals, and the thoracic duct. The milky appearance sometimes exhibited by the serum of the blood, when drawn shortly after a full meal, is probably due to the molecular base, and not to the absorption of milk, to which it has been erroneously attributed.

The lacteals appear to be endowed with a *selective* power of absorption, receiving only certain substances presented to them, and rejecting others. Medicinal or colouring matters very rarely enter them, being taken up by the blood-vessels in preference.

The chyle drawn from the lacteals before they enter the mesenteric glands contains the molecular base in maximum quantity, likewise a little albumen dissolved, and some salts, but no trace of fibrine. It also contains some oil-globules, which are stated to be more abundant in the chyle of man and the carnivora than in that of the herbivora.

The first change which the chyle undergoes in its passage towards the blood is observed just before the lacteals enter the mesenteric glands. It consists in the appearance of fibrine, and the diminution of the oil-globules. The fibrine is formed at the expense of the albumen, which subsequently diminishes in proportion as the fibrine increases. The proper *chyle-corpuscles* now begin to appear, and are constantly found throughout its subsequent course. They are particularly abundant in chyle drawn from a mesenteric gland.

The gradual increase of the albumen and fibrine in the progress of the chyle, apparently at the expense of the oily matters, is very difficult to account for. There can scarcely be a conversion of the one into the other. It is much more probable that the change of composition is due to an admixture of lymph which has been lately asserted to occur in the mesenteric glands, depending upon the anatomical arrangement of the lymphatics of the intestines. Two layers of these vessels are stated to exist, one superficial, the other deep-seated,—communicating with one another. From the deep-seated layer there go off lateral offsets to each villus; these are the true lacteals, and their contents will consist of the matters absorbed by the villus until they pass into the mesenteric glands, where they mingle with the true lymphatics of the intestine, and thus derive the chyle-corpuscles, albumen, and fibrine,—the quantity of the molecular base only *relatively* diminishing.

The chyle-corpuscles, according to Carpenter, originate in the mesenteric glands. They are supposed, by him, to be the altered epithelium-cells which line the lacteals in their passage through these bodies. The epithelium of the lacteal before it enters the gland is thin and scale-like: within the gland, it is composed of numerous layers of spherical nucleated cells, of which the superficial ones are easily detached, and appear to be identical with the chyle-corpuscles. They vary much in size, from a diameter of 1-700th to 1-2600th of an inch. This variation in size depends, probably, upon the period of their growth. They are granulated on their surface; but the nuclei cannot, very readily, be defined. There is a strong resemblance between them and the colourless corpuscles of the blood,—especially in the thoracic duct. The *function* of the chyle-corpuscles may be inferred to be, to convert the albumen of the chyle into fibrine; for the chyle is found to coagulate spontaneously only when these corpuscles are present, and the amount of fibrine observed is in proportion to the diminished quantity of albumen. After leaving the mesenteric gland, the lacteals converge towards the *receptaculum chyli*, into which, also, the lymphatics discharge. From the receptaculum arises the *thoracic duct*, which passes upwards in front of the spine, to ter-

minate at the junction of the left subclavian and jugular veins. A smaller duct receives some of the lymphatics of the right side, and there terminates at a corresponding part of the venous system; but none of the lacteals discharge into it. The chyle taken from the receptaculum and thoracic duct, coagulates like blood; the clot comprising most of the chyle-corpuscles; the serum closely resembling the serum of blood. Sometimes the separation into serum and clot is not so distinct, the coagulum appearing like a jelly.

There is some slight difference of opinion as to the *mode* in which lacteal absorption is effected. Each intestinal villus is composed of a process of basement-membrane, covered over with an epithelium, and containing a lacteal embedded in a mass of "absorbent-cells." According to Goodsir, this epithelium is rapidly desquamated during digestion, so as to allow the chylous fluid to come into immediate contact with the basement-membrane, which it penetrates by endosmose, and then, in like manner, it passes into the absorbent cells, which rapidly swell up and burst open, and delivering their contents (probably somewhat altered in character) to the lacteals. These, also, finally absorb it, and then it passes onwards to the thoracic duct. The Webers are of the opinion that the epithelium does not desquamate so completely as stated by Goodsir; they suppose that the epithelium-cells exert some modifying influence over the oily matters.

II. The Lymph.—The lymph is the pellucid fluid found in the lymphatics. These vessels are distributed throughout the whole body, chiefly in the skin. They commence neither by closed nor open extremities, but from a network, from which the trunks arise. In their course they pass through glands termed *lymphatic glands*, strongly resembling the mesenteric; and finally terminate in the same general reservoir—the receptaculum chyli.

The lymphatic system is in its most developed state in the mammalia, the vessels having firmer walls, and more numerous valves than in the lower classes. The glands are also more numerous in them; these resemble, in their general characters, the mesenteric glands.

The chief points of distinction between lymph and chyle are the following:—lymph is perfectly transparent and colourless; chyle is opaque and milky; lymph contains much less solid matter, and is nearly destitute of oily materials. The following table shows the distinction between chyle and lymph:

	Chyle.	Lymph.
Water, - -	90·237 - -	96·536
Albuminous matter, -	3·516 - -	1·200
Fibrinous matter, -	0·370 - -	0·120
Animal extractive matter,	1·565 - -	1·559
Fatty matter, -	3·601 - -	a trace.
Salts, - - -	0·711 - -	0·585
	100·00 - -	100·00

From this analysis, it appears that the chief chemical difference between the chyle and lymph is the greater proportion of assimilable substances—albumen, fibrine, and fatty matter—contained in the former.

Function of the Lymphatics.—At the time of their discovery by the Hunters they were supposed to be the exclusive agents of absorption; hence their name of *Absorbents*. It was formerly supposed that the lymphatics took up and carried out of the system all the effete matter which resulted from the constant waste and disintegration of the organs. This doctrine, however, is not tenable; for it seems absurd to imagine that this effete matter would be mixed up with the newly-ingested aliment, and so thrown into the blood, instead of being immediately carried out; and the actual composition of the lymph also is opposed to it, since it contains highly nutritious substances. The true function of the lymphatic or absorbent system is connected with *nutrition*. It receives the liquid portion of the plasma, which passes out of the capillaries in the process of nutrition, and conveys it back again to the blood. It also takes materials which are capable of being used for the nutriment of the system, whether these be furnished by the external world, or by the disintegration of the system itself. It is true that other substances are at times found in the

lymphatics—as, for instance, *bile*, when some obstruction exists in the gall-ducts. So, also, the lymphatics in the neighbourhood of a large abscess have been found to contain *pus;* and when the limb of an animal, around the upper part of which a bandage is tied, is immersed for some hours in tepid milk, the lymphatics of the skin are found to contain that fluid; also, when saline substances are applied to the skin, they are usually more readily detected in the lymphatics than in the veins. But these facts only prove that the walls of the lymphaties are permeable by substances in a state of solution. The more ready absorption of such substances by the lymphatics, than by the veins of the skin, may be accounted for from the fact of the very free distribution of the lymphatics upon the skin, and the greater tenuity of their walls. In the lungs, the case is different,—matters, when injected into the pulmonary tissue, finding their way much more readily into the blood-vessels, on account of their more abundant existence. As regards the absorption of pus from an abscess or ulcer, the probability is that the absorbents must themselves have been laid open in the process of ulceration, since the pus-globule is too large to have gained admittance in any other way.

Hence, it appears that the lymphatics, as well as the lacteals, convey nutritive materials, although derived from a different source. If this view be correct, we must look to the veins as the true absorbents of the effete matters of the body.

The fluid of the thoracic duct, as we have seen, is made up by the admixture of the chyle and lymph. It contains the chyle-corpuscles and fibrine, in the maximum quantity, the oily matter in minimum quantity, and the albumen in medium quantity. It resembles the blood in every respect, except that it contains less fibrine and none of the red corpuscles, though the latter sometimes find their way into it, so as to communicate a perceptible reddish tinge. It is the belief, however, that this is the result of accident, the operation for exposing the thoracic duct, having laid open some of the lacteals or lymphatics, which took up blood by their open mouths, and then transmitted it to the duct. Mr. Gulliver and others suppose, on the contrary, that the red corpuscles are really

in the process of formation in the thoracic duct, and that they are formed from the chyle-corpuscles, which are identical with the white corpuscles of the blood. Carpenter adopts the former view.

The movement of the chyle and lymph along the absorbents is ascribed to a sort of peristaltic action of the fibrous or middle coat of these vessels. This fibrous structure is particularly evident in the thoracic duct. The retrograde movement is prevented by the *valves* with which the absorbents are supplied. The general movements of the body may also assist in propelling the chyle and lymph onwards; but the force exerted by endosmose, in the passage of the liquid plasma into the lymphatics, is also concerned in it. In some of the lower animals, as in the frog, there exist several propulsive organs in the course of the lymphatics, termed *lymphatic hearts.*

The lymphatic system is liable to various pathological conditions. In scrofulous constitutions it is particularly exposed to inflammation; the external lymphatic glands more especially suffer. In some cases the lymphatics of some particular part of the body, as of the face and neck, are attacked with a peculiar sort of inflammatory action, or rather lymphatic congestion, differing from ordinary inflammation in wanting the redness, increase of temperature and pain, but exhibiting only a diffused swelling, which frequently passes rapidly off. In other cases, it results in a white and indurated swelling, of a very permanent character. The *elephantiasis of the Arabs* is believed to be a disorder connected with a somewhat similar condition of the lymphatic system. The induration in some of these cases attains an enormous size.

III. The Blood.—The blood may be regarded as containing all the elements of the organism in the fluid state. As it is the most complex of all the fluids, as regards its chemical composition, it is exceedingly prone to undergo change, either spontaneously or by the introduction into it of morbific agents. Moreover, in its circulation through the system, it yields up to the various tissues the materials for their reconstruction, and receives from them the products of their decay; hence, its characters are incessantly changing, even in the ordinary acts of life.

While circulating in its vessels, it presents a perfectly homogeneous appearance, of a somewhat oily aspect, and having an average specific gravity of 1050. Its colour varies in different animals: it is colourless in the mollusca, crustacea, and some of the insecta; it is yellow in some others; in the vertebrata it is red. Examined by the microscope, while in the living body, it is found to consist of a clear and nearly colourless liquid—the *liquor sanguinis*, in which float numerous solid bodies termed *corpuscles*. When drawn from the body and left to itself, its elements undergo a new arrangement, called its *coagulation*, by which process it separates into two distinct portions, the solid portion called the *cruor*, *crassamentum* or *clot*, and the liquid portion, termed the *serum*. The clot consists of the fibrine, which, in the process of coagulation entangles the red corpuscles in its meshes; and it becomes dense in proportion to the amount of fibrine it contains. The serum consists of the albumen and saline matter dissolved in water. There is usually some serum remaining in the clot, from which it may be removed by pressure. The difference between the composition of the blood when circulating, and in the coagulated state, may be thus stated:

WHEN CIRCULATING.

Fibrine, . . . Albumen, . . . Salts, ...	In solution, forming Liquor Sanguinis.
Red corpuscles,—Suspended in Liquor Sanguinis.	

WHEN COAGULATED.

Fibrine, . . . Red Corpuscles,	Crassamentum or Clot.
Albumen, . . . Salts, ...	In solution, forming Serum.

The coagulation of the blood is entirely due to the fibrine; the red corpuscles are passive, as may be shown in various ways: by filtering the freshly-drawn blood of a frog, the liquor sanguinis passes through perfectly clear, and subsequently coagulates, leaving the corpuscles on the filter; by constantly whipping freshly-drawn

blood with a bundle of twigs, the fibrine will adhere to them in long shreds, while the red corpuscles will remain suspended in the serum without any tendency to coagulate.

The length of time which elapses before coagulation, after the blood has been drawn, varies very much. As a general rule, the more elaborated and concentrated the fibrine is, the more slowly will it coagulate, and the firmer will be the clot. Thus, when a quantity of blood is drawn at one bleeding into several vessels, that which is received into the first will coagulate most slowly, but form the firmest clot; while that drawn last will coagulate more rapidly, but the clot will be thinner. The coagulation is accelerated by heat, and retarded by cold; but it is not prevented by extreme cold; since, if blood be frozen as soon as drawn, it will coagulate on being thawed. Again, the coagulation is accelerated by exposure to the air; and it is retarded, though not prevented, by complete exclusion from it. Constant agitation will delay the coagulation; but that mere *rest* is not the cause of it, is proved by the experiment of including a portion of blood between two ligatures in a living vessel; it will remain fluid for some time. Various chemical agents also retard this process, especially solutions of the neutral salts; but they do not prevent it: they seem, however, to produce some mechanical change upon the fibrine, hence the clot is not so firm after their use. Carbonic acid is usually extricated during coagulation.

The coagulation of the blood is no proof of its death, as was thought by Hunter; on the contrary, it is an evidence of vitality, since, as has been shown, the very first act of its organization is coagulation; when separated from a living surface, however, the coagulation of the blood may be regarded as the last act of life, since it afterwards passes into a state of decomposition.

The coagulating power of the fibrine is sometimes destroyed, so that the blood when drawn will not separate into serum and clot. This may result from poisonous matter introduced from without, which acts as a ferment—as seen in malignant typhus fever, in glanders, &c.; or from some morbid condition originating in the system, depending upon a deficient nutrition or excretion, as seen in scurvy, purpura, asphyxia, and in animals over-driven; and

also from violent shocks or impressions upon the nervous system, as electricity, lightning, concussions of the brain, coup-de-soleil, &c. Sometimes there is a remarkable *retardation* in the coagulation of the blood,—its fluidity continuing for some days, but ultimately coagulating.

The relative proportions of serum and clot vary. When the coagulation is rapid the clot retains a large portion of serum, increasing its apparent bulk. It is said that coagulation occurs more rapidly in metallic vessels than in those of glass or earthenware, and that the proportional amount of clot is much increased.

Analysis of the Blood.—The following is the proximate analysis of the blood, according to Simon.

Water.	
Proteine compounds,	Fibrine. Albumen. Globuline.
Colouring matters,	Hæmatine. Hæmaphæine.
Extractive matters,	Alcohol-extract. Water-extract. Spirit-extract.
Fats, ...	Cholesterine. Serolin. Red and white solid fats containing phosphorus. Margaric acid. Oleic acid.
Salts, ...	Albuminate of soda. Phosphate of lime, magnesia, and soda. Sulphate of potassa. Carbonates of lime, magnesia, and soda. Chlorides of sodium and potassium. Lactate of soda. Oleate and margarate of soda.
Iron,—Condition doubtful.	
Gases, ...	Oxygen. Nitrogen. Carbonic acid.
Sulphur.	
Phosphorus.	

Traces of the following substances are occasionally found:—sugar, urea, biline, and its acids, biliphæine, or yellow colouring matter of bile, certain salts, copper, manganese, and silica. According to Bernard, glucose is always found in the blood of the liver, and of the right side of the heart. As many as forty-two principles have been discovered in the blood at various times; Lecanu has reduced the number to twenty-seven.

The following may be taken as the average amount of the more important constituents of the blood in health, although they are subject to considerable variation:—There is a greater amount of solid matter in the blood of the male than in the female, except in the case of albumen; in 1000 parts of blood the quantity of albumen amounts to about 70, with very little variation. The corpuscles vary considerably, rising in the male as high as 186, sinking to 110·5, average—140; in the female they may rise to 167, and sink to 71·4, average—112. The greater variation in the case of the female may be due to the catamenial discharge, which diminishes the quantity of corpuscles. The average amount of fibrine in the male is 2·2; it may rise to 3·5, or 4, but does not sink below 2; in the female the average is about 2; it may rise to 3, and fall to 1·8. The fatty matter varies from 3·5 to 4·5: the variation is probably due to the amount contained in the food. The saline constituents, obtained by drying and incinerating the whole mass, usually amount to between 6 and 7 parts in 1000; more than one-half of which are composed of the chlorides of sodium and potassium,—the remainder is made up of the tribasic phosphate of lime and magnesia, sulphate of soda, and some phosphate and oxide of iron. Most of these salts are held in solution by the serum. The iron is contained chiefly, if not entirely, in the red globules. The alkaline reaction of the serum is thought to be due to the tribasic phosphate of soda. The quantity of water is estimated at about 780 to 785 parts. There are also some extractive matters, and some "ill-defined animal principles." We will now consider some of these constituents separately.

Red Corpuscles.—These exist very sparingly in the blood of

the invertebrata, which is consequently of a *white* colour. Their proportion in the blood of the vertebrata also varies,—seeming to be connected with the relative activity of the respiratory function in each case. Their form is that of a flattened disk, which is circular in man and most of the mammalia, but oval in birds, reptiles and fishes, and a few mammals. These disks are flattened cells, whose walls are transparent, but whose contents are coloured. This can easily be shown, by floating them in water, when this fluid will be absorbed into the cells by *endosmose*, and cause them to swell out, and finally to rupture. If they be put into a thick solution of gum or sugar, the movement will be from within outwards, so as to cause the disks to have a shrunken appearance. Hence, in examining the blood-disks, they should be floated in a fluid of about the same density as serum. As respects the existence of a *nucleus* in the red corpuscles, it is the present belief, that in those of mammalia there is no distinct nucleus,—the dark spot which is seen in their centre being merely the effect of refraction, in consequence of the double-concave form of the disk: when the corpuscles are treated with water, by which their form is altered, this dark spot disappears. Some physiologists contend for the existence of a nucleus in the mammalian corpuscles, although they cannot be seen, on account of their high refractive power. The nucleus, however, is distinctly visible in all the other vertebrata, as may easily be made evident by treating the corpuscles with water, when the contents will escape from the rupture of the cell-wall, and the colouring matter can be distinguished from the nuclei. The nucleus consists of an aggregation of minute particles, which are doubtless the *germs* of future cells.

The size of the red corpuscles varies very much, not only in different animals, but even in the same animal. Thus, in man, it varies from the 1-4000th to the 1-2800th of an inch; the average being about the 1-3400th. This is also about the average size of the mammalian corpuscles in general, with the exception of the musk-deer, in which they are less than the 1-12,000th of an inch in diameter. The camel tribe, alone of mammals, has the blood-disks of an oval shape; their long diameter being about

the size of that of man; the short diameter only about one-half of this. In birds, the diameters are to each other about as 1 to $1\frac{1}{2}$ or 2. The size of the disks usually corresponds with the size of the bird: thus, in the ostrich, the long diameter is about 1-1650th of an inch, and the short diameter, 1-3000th: while, in the sparrow, &c., the long diameter is about 1-2400th, and the short not more than one-half of this. The corpuscles are largest in reptiles. Those of the frog are peculiarly suited for study: their long diameter is about the 1-1000th of an inch, and their short diameter about the 1-1800th. The proteus, siren, and such species are remarkable for the large size of their blood-disks; thus the long diameter of the corpuscles of the proteus is about the 1-337th of an inch. In those of the siren, it is about 1-435th of an inch. The long diameter of the nuclei of these disks is about the 1-1000th of an inch, which is more than three times the length of the entire human corpuscle. The variation in the size of the corpuscles in the same animal is easily understood, when we consider them to be cells at different stages of growth. The form of these corpuscles is often observed to change during their circulation, owing to the pressure; thus, in the narrow capillaries, they may be observed to become elongated, twisted, or bent, to facilitate their passage.

The chemical composition of the walls and nuclei of the red corpuscles is very different from that of their contents. The former are composed of *globuline*, which is a proteine-compound; the latter consist of a proximate principle termed *hæmatine* or *hæmatosine;* and it is to this that the red colour of the blood is due; its formula is $C_{44}H_{22}N_3O_6+Fe$; the iron forms an essential constituent of it. This proximate organic principle is found only in the blood of vertebrata. It exists in the interior of the red corpuscles in a liquid state, but is not chemically combined with the globuline, since it can be mechanically washed out from it by water. About 5·8 parts of hæmatine exist with 100 parts of globuline (Berzelius); but its quantity varies considerably in disease, ranging between 8·5 to 3·3 (Simon). It has a very strong affinity for albumen, and is associated with it in the blood-corpuscles;

Lecanu has, however, succeeded in separating them. When isolated, it exhibits a blackish-brown colour, and a metallic lustre; it is destitute of odour and taste; insoluble in water, alcohol, or ether, if pure, but soluble if associated with a small quantity of albumen, acids, or alkalies, causing a deep blood-red colour. It has been supposed that the hæmatine combined chemically with the alkalies; but if so, they do not lose their alkaline reaction by the combination. Hæmatine is the only animal principle known to contain *iron*, which exists in it in the proportion of eight to ten per cent.; or six per cent. according to Mulder. There is a difference of opinion in relation to the condition of the iron, Berzelius supposing it to be in the metallic state, whilst Liebig believes it to be in the condition of an oxide. It is true, the oxide cannot be precipitated by alkalies, nor recognised by ferrocyanide of potassium; but it is well known that the presence of certain organic matters may prevent this, and it is possible it may be the case with the blood.

The red colour of the blood was, at one time, supposed to be due to the presence of the iron; this, however, has been disproved by Scherer. According to Mulder, the iron is combined with hæmatine just as iodine is with sponge.

The difference between the colour of arterial and venous blood has been supposed to indicate some difference in the condition of the hæmatine in the two cases. In the first case, the blood gives out oxygen, and becomes charged with carbonic acid; in the second, it gives off carbonic acid, and acquires oxygen. A similar change in colour may take place out of the body under similar conditions; thus venous blood, when exposed to the air, and particularly if exposed to oxygen, acquires a florid hue; while arterial blood, when in contact with carbonic acid, becomes as dark as venous blood. The mere removal of the carbonic acid is not sufficient to restore the arterial colour, since this can be accomplished by hydrogen; it requires the presence of oxygen, or the addition of saline matter to the blood. Liebig's opinion is that this difference is owing to oxygen, and that the *iron* is concerned in the change of colour; he believes that the iron exists in venous blood

in the state of carbonate of the protoxide, and in the arteries as the peroxide. Mulder, on the other hand, denies that the hæmatine undergoes any chemical change in passing from arterial to venous blood, and ascribes the change of colour to a physical alteration in the shape of the blood-corpuscles; he asserts that they become bi-concave in arterial blood—a form which reflects most light, and which, consequently, causes the mass of blood to appear of a bright tint; and bi-convex in venous blood,—a shape which disperses the rays of light, and so produces a darker hue. These speculations, however, though very ingenious, want absolute confirmation; they may even, to a certain extent, be reconciled, since it is known that oxygen will confer the arterial hue upon venous blood, by causing a change in the shape of the corpuscles; and carbonic acid will, in the same manner, produce the venous hue in arterial blood.

In certain low forms of disease, as scurvy and bad cases of typhoid fevers, the hæmatine abandons the globuline in the blood-corpuscles, and is washed out by the serum, to which it imparts a characteristic reddish hue, so indicative of danger in these complaints. It would appear that the saline elements of the blood are concerned in maintaining its integrity. Dumas has proposed a simple experiment for ascertaining the existence of this disordered condition of the blood, as a means of founding a prognosis; it is to receive a few drachms of the blood upon a filter, moistened with a strong solution of sulphate of soda, which prevents the coagulation; then, if the serum filters through perfectly clear, the evidence is that the corpuscles are yet in a healthy condition.

Hæmatine is never found in vegetables; it is not easy to account for its origin in the animal system; Mulder supposes it to be generated from the constituents of the blood while circulating. Oxygen would seem to be essential to its formation, since it is stated, that in an egg kept from the influence of this gas, during incubation, no hæmatine is formed. We are also ignorant of the destination and uses of this principle in the animal economy. Most probably it is in some way connected with the development of the nervous force. It is sometimes rapidly diminished in

disease, as is witnessed in anæmia and chlorosis; again, it is often rapidly reproduced by a generous diet and chalybeates. Like all other animal principles, hæmatine is constantly undergoing disintegration and renovation. Simon supposes that the products of its decomposition are to be found in the colouring matter of the urine, named by him hæmaphæine, and in the colouring matter of the bile—biliphæine.

As regards the *origin* of the red corpuscles, it may be considered as pretty well established, that, like other simple isolated cells, they are constantly being reproduced, and as constantly dying out. Bleeding rapidly diminishes them; the same effect is produced by chlorosis; on the contrary, they are rapidly regenerated under the use of iron, and in plethora. There is some difficulty in supposing that the colourless corpuscles serve as nuclei for future red corpuscles, as maintained by Wagner, Gulliver, and others, since while the diameter of the former is very constant, that of the latter varies extremely. Their original formation has been clearly traced to the minute granules (probably cell-germs) in the cells of the germinal membrane. These become blood-corpuscles, and their subsequent increase and reproduction can only occur like the increase of any other cells, by the evolution of successive generations of germs from the parent. This multiplication may arise, either from a division of the cell into smaller ones, which afterwards attain their full size; or from the corpuscles assuming a sort of hour-glass form, by contracting across the middle, and by an increase of this contraction, causing a division of them into two.

The opinion of many of the best authorities of the present day (Kölliker, Vogt, Cramer, Kirkes and Paget) is that in the vertebrata *two* sets of red corpuscles are developed, at different periods of embryonic life; the first set, which exists alone in the blood till lymph and chyle begin to be formed, and a second set, which are formed from the lymph and chyle-corpuscles, and gradually supersede the first. The first set appears to be developed from the embryo-cells of the mucous layer of the germinal membrane. They are distinctly nucleated; those of the human embryo are circular, full-coloured, and of an average diameter of

the 1-2500th of an inch; that of the nuclei about 1-5000th of an inch. In their earliest stage they appear to be full of minute granules, and to multiply by a segmentation of the nucleus, each half of which becomes invested with an envelope, and thus forms an independent cell. The star-shaped cells observed in the vascular area seem to become elongated, and finally to have their processes fused into one another,—thus forming vessels; the nuclei of the cells become the corpuscles. In the progressive development of the embryo, when the lymph and chyle-corpuscles begin to be formed and added to the blood, they supersede those just described. For some time the two sets of corpuscles appear to be mingled in the blood, the first being easily distinguished from the second by their larger size, distinct cell-walls, and their small, well-defined nuclei. As just stated, they gradually give place to those of the second set, and cannot be observed, according to Kirkes and Paget, in the human embryo, after two months old, unless in cases of arrested development. These last-formed corpuscles retain their nucleated character in the oviparous vertebrata throughout life; but in the mammalia, including man, the whole of the contents clear up subsequently, so as to present the appearance of a perfect non-nucleated cell.

Various theories are held in relation to the *function* of the red corpuscles: Hunter considered them the least important part of the blood; Magendie supposed their only use was to demonstrate the circulation. Wagner, Henle, Schultz and others believe that they elaborate the fibrine of the blood out of the albumen; but as they do not exist in the invertebrata, they cannot, according to Carpenter, be essential in the plastic or formative functions. Again, their number increases in those animals whose respiratory process is active,—hence they are believed to be carriers of oxygen to the various tissues, and of carbonic acid from these tissues to the lungs. Liebig supposes the *iron* to be the real agent in the respiratory process,—becoming changed from a protoxide to a peroxide, by receiving oxygen from the lungs; and again becoming a protocarbonate in the systemic capillaries by giving up its additional oxygen, and receiving carbonic acid in return. This,

however, is speculation, as there is no proof of the iron being in the state of *protoxide.* It is quite certain that the animal functions are greatly dependent upon the red corpuscles for their activity. Simon supposes them to carry the oxygen, not for the general purposes of the economy, but for their own particular use, —to convert the globuline into the urea, biline, and choleic acid of the blood, and the hæmatine into hæmaphæine. It is certain that the large amount of oxygen carried into the system is not needed for the conversion of albumen into fibrine, since these, as we have seen, are so nearly identical.

Besides the red corpuscles of the blood, there are others called *colourless* or *white corpuscles,* which seem identical with those of the chyle and lymph. They differ in their appearances from the red corpuscles: thus, while the size of the latter varies very much in different animals, that of the white corpuscles has a great degree of uniformity, being in all cases, very near 1-3000th of an inch in diameter. Hence, it would seem unlikely that the one could ever be converted into the other. Again, their appearance under the microscope is different; the colourless corpuscles are filled with minute granules, which are seen to be in active movement. By the action of a dilute solution of potash, these cells rupture, discharging their molecules, which are doubtless germs of new cells. Moreover, when the corpuscles rupture spontaneously, the fluid which they set free shows a tendency to assume a fibrous arrangement. The distinction between the two may also be perceived in the capillaries of the frog's foot, in which the colourless corpuscles are seen to remain close to the sides of the vessel, where the movement is slow, while the red corpuscles move rapidly through the centre of the current. Often the colourless corpuscles evince a tendency to adhere to the side of the vessel.

The *function* of the white corpuscles is, according to Dr. Carpenter, to elaborate fibrine out of the albumen of the blood. This theory is sustained by the following considerations:—They are found in *all* animals possessing a circulation,—the red corpuscles are only found in the vertebrata. They exist wherever the production of fibrine is going on, and their number bears a close rela-

tion to the amount of fibrine; thus, in inflammation, where the fibrine is so much increased, the number of white corpuscles is proportionally augmented. They are also seen in great quantities in the vessels of inflamed parts, and likewise in the exudations from the blood upon wounded or inflamed surfaces. So again, in the embryonic condition of animals, when the *formative* process is particularly active, especially in the early stage of fœtal life, the white corpuscles are very abundant. We may consider the white corpuscles, then, as isolated floating cells of a transitional character, whose function is to work up the organizable material, albumen, as it is thrown into the circulation, into fibrine, for the supply that is constantly demanded by the nutritive processes. This they effect by a simple process of cell-growth, generation succeeding generation, just like the vegetable-cells of plants, or the transient generations of cells in the egg, whose office is to elaborate the proper material for the future nutriment of the organized structure.

The *Fibrine* of the blood is the highly organized material from which the various tissues and organs are nourished. It exists in the fluid state, and is withdrawn for the purposes of nutrition almost as fast as it is formed: the demand being supplied partly, as just shown, by the elaboration of the white corpuscles, and by the chyle and lymph. A proper amount of fibrine is requisite in the blood to enable it to circulate in the vessels. If defibrinized blood be injected into the vessels of an animal, typhoid symptoms are produced.

The *Albumen* is the raw material out of which not only the fibrine, but many other substances are generated: thus the albuminous compounds of the secretions, the horny matter of the skin, hair, nails, &c., the gelatinous tissues, the walls of the red corpuscles, and others are transformations of albumen. The constant supply which is needed, is afforded by the food, which, as has been shown, must be converted into albumen, by the process of digestion.

The use of the *Saline Matters* is chiefly to supply the mineral materials requisite for the composition of certain tissues and secre-

tions, as bone, teeth, urine, sweat, &c. There seems to be an instinctive desire among all animals for salt; it is not merely useful as a condiment, but it is essential to the healthy condition of the animal.

The *Fatty Matter* is derived from the food; its chief use is for the maintenance of animal temperature by the combustive process. What is superfluous of it may either be deposited as fat, or eliminated by the liver, the sebaceous follicles, or the mammary gland in females. The blood also appears to contain a fat peculiar to nerve-matter, containing nitrogen and phosphorus; but it is uncertain how it is generated.

The *Water* of the blood exists in large quantities, its presence being all-important for the proper fluidity of the blood. The quantity of water is very nearly fixed, in a state of health; any excess constantly passing off by the different secretions; and it is as constantly renewed from the fluids received into the stomach, or by absorption through the skin and lungs. A deficiency of water occasions *thirst.*

Pathological Changes in the Blood.—The normal proportions of the constituents of the blood are liable to great variation in disease, and this may be either the cause or the effect of the disease. For example, some local injury produces an inflammation of a part; the relation of the part to the blood which passes through it is altered; in consequence of this, the blood itself is changed in its properties, and so becomes the source of disturbance to other remote parts of the system.

On the other hand, Fever may be taken as an example of a contamination of the blood proving the cause of general disease—the blood being originally affected by the introduction into it of some morbific matter.

The following is Simon's table of the modifications of the blood in disease :—

1. *Hyperinosis* (an excess of fibre), including inflammations, erysipelas, phthisis, medullary carcinoma, and others.

2. *Hypinosis* (a diminution of fibre), including all the fevers,

especially typhus, and the eruptive diseases, together with cerebral hemorrhage.

3. *Spanæmia* (poverty of the blood), including anæmia and hydræmia, carcinoma, scrofulosis, scorbutus, hemorrhages, and plague.

4. *Heterochymeusis* (foreign mixtures), including cholera, morbus Brightii, diabetes, icterus, &c.

In inflammation, the quantity of fibrine is vastly increased, mounting up as high as seven, eight, or even ten and a half parts in a thousand, according to the intensity of the case. There is also constantly observed an increase of the tritoxide of proteine in the blood, and a great disposition of the red corpuscles to arrange themselves in rows. The white corpuscles are also increased in number, and they separate from the red, adhering rather to the fibrine. These phenomena may be witnessed in a single drop of inflammatory blood under the microscope. The increased amount of fibrine is an invariable accompaniment of inflammation, whether or not it be complicated with other disorders.

In fevers there is a diminution of fibrine, and rather a tendency to an increase of the red corpuscles. The loss of fibrine is particularly seen in typhoid fevers, being reduced sometimes as low as 0·9; but if any inflammation should be developed in the course of the fever, immediately the proportion of fibrine rises. An excess of fibrine is not much lessened by copious bleeding, even if this be repeated; but certain medicines appear to exert an influence upon it, particularly mercury. A deficiency of fibrine produces a tendency to congestion and hemorrhage; hence the liability to these disorders, in the course of fevers.

An unusual amount of red corpuscles produces the state of system called *plethora* or fulness. In such cases there is a tendency to local congestions, and to hemorrhages. Hence we can understand the value of bloodletting in such cases;—it acts by rapidly diminishing the quantity of red corpuscles. Plethoric persons are not more exposed than others, to inflammation. In apoplexy, the blood exhibits a diminution of fibrine. The opposite state of system to plethora is *anæmia*, in which there is a great diminu-

tion of red corpuscles. This is often caused by repeated hemorrhage. Chlorosis exhibits the same diminution of red corpuscles,—in extreme cases they sink as low as 27, (standard, 127). The influence of a generous diet, and particularly of the administration of iron, in reproducing these corpuscles, is very evident. The blood in anæmia and chlorosis exhibits the *buffy coat,* since this depends, as will be shown presently, upon the greater relative amount of fibrine to red globules.

In scrofula there appears to be a diminution both of red corpuscles and fibrine. The same condition of the blood was found, by Andral, in the various cachexiæ. The amount of albumen in the serum is diminished in albuminuria or Bright's disease of the kidney, in which an excess of it is found in the urine. According to Andral, the amount of albumen present in the urine is exactly proportionate to the diminution of it in the serum. The proportion of the saline matters is not so liable to be altered by disease.

The blood may also be affected by the presence of other matters, either such as have been introduced from without, as medicinal agents, or a specific virus acting as a ferment, or such as are produced within, and which ought to have been removed by the process of excretion, such as carbonic acid, urea, uric acid, the biliary and other matters. Some of the specific matters introduced into the blood from without appear to poison it, destroying its vitality, and causing general decomposition of the solids and fluids, even before death takes place. Such is the case in malignant fevers, in glanders, in the bites of venomous serpents, &c.

The *buffy coat* is the appearance which the blood assumes when drawn, in cases where the amount of fibrine is relatively increased over the red corpuscles. Thus, in inflammation, the fibrine is *actually* very much increased, causing a delay in its coagulation. This allows the corpuscles time to sink to the bottom, leaving the upper part of the clot composed only of fibrine, which is consequently nearly destitute of colour, and very tenacious in its character; while the lower part of the clot is of a very deep colour, and very friable. In these cases, the upper stratum, or buffy coat, being composed of highly elaborated fibrine, undergoes a slow

contraction after coagulation, which draws in the upper edges of the clot, and produces the *cupped* appearance. The buffy coat is also seen in cases where there is no increase of fibrine, but where there is simply a diminution of the red corpuscles. Thus in chlorosis, the buffy coat is as evident as in inflammation; but the size of the coagulum is much less, on account of the diminished amount of solid matters.

SECTION IV.

OF THE VOICE—SPEECH.

Nearly all air-breathing vertebrate animals possess the faculty of producing sound, or *voice*, in some part of the respiratory apparatus. In many animals this sound admits of being variously modified or altered during and after its production; one of the results of such modification in man, is *speech*. Vocal sounds and articulate language, or speech, are then two distinct things, and are produced at different places,—the larynx being the instrument of the voice, and the mouth, that of speech. The voice is the result of a current of air passing through a certain portion of the respiratory tube, so constructed as to be made to vibrate. It is frequently modified by muscular action.

In reptiles, the vibrating apparatus is very simple, being composed of a slit bounded by two contractile lips: the only vocal sound of these animals is a *hiss*. In birds, the vocal apparatus is at the lower extremity of the trachea, at its subdivision; it is very complicated in singing birds, but the arrangement for their breathing is much the same as in reptiles. In mammals, the vocal organ and the regulator of respiration are associated in the larynx. Man alone has the faculty of *language*.

The larynx is composed of four cartilages—the cricoid, thyroid, and two arytenoid. The *cricoid* cartilage forms the summit of the trachea. It is a bony ring, deeper behind than before; and it articulates with the thyroid cartilage by means of the lower cornua of the latter, in such a way as to form a little de-

pression between the two in front. The two arytenoid cartilages are placed upon the upper surface of the back of the cricoid, and are so articulated as to enable them to be approximated, or separated from each other. The *vocal cords* or vocal ligaments (thyreo-arytenoid) extend from the tops of the arytenoid cartilages across to the front of the thyroid cartilage. They are composed of yellow fibrous or elastic tissue. It is upon the condition of these ligaments that the different modifications of the voice depend. They are made tense by the depression of the front of the thyroid cartilage as it approaches the cricoid, and relaxed by its elevation; by this action the *pitch* of sound is regulated. Again, they are brought into more or less close apposition by the rotation of the arytenoid cartilages;—this arrangement is necessary for the perfection of *tone*. The *rima glottidis* is the chink or fissure between the vocal cords; when there is no sound, it assumes the shape of the letter V. The mucous membrane lining the larynx is reflected over the vocal ligaments, dipping down into the spaces between them to form the ventricles of Galen or Morgagni.

Hence, there are two sets of movements concerned in vocalization:—the regulation of the relative position of the vocal cords, and the regulation of their tension. The first is accomplished by means of the arytenoid cartilages, which are made to diverge by the action of the crico-arytenoidei laterales muscles; by this means the vocal ligaments are drawn asunder, and the rima-glottidis opened. The second, or that concerned in the tension of the ligaments, is effected by the approximation or separation of the thyroid and cricoid cartilages in front; thus, they will be made tense by the contraction of the crico-thyroidei muscles, assisted by the sterno-thyroidei; and they will be relaxed by the action of the thyro-arytenoidei muscles, aided by the thyro-hyoidei. The muscles which govern the aperture of the glottis are also intimately connected with respiration; they are frequently the seat of spasmodic action, especially in children. By an effort of will, we can close the glottis, through their means; and a spasmodic movement of this sort occurs in coughing and sneezing, whereby irritative substances are expelled. The nerve of motion for these muscles

is the inferior or recurrent laryngeal;—the afferent or sensory nerve is the superior laryngeal; if it be divided, no reflex respiratory movement can be excited by irritating the lining membrane of the larynx.

When in a state of rest, as during ordinary respiration, the vocal cords appear to be as much relaxed as possible, and widely separated from each other. In order to produce a vocal sound, they must be approximated, and at the same time put to a certain degree of tension. Both these movements take place at the same time. The size of the aperture between the vocal ligaments varies with the *note*, being smaller in proportion as the note is high.

It has been satisfactorily demonstrated that the inferior laryngeal ligaments are the true agents in the production of the voice; being thrown into vibration by currents of air impelled over their edges. Thus, a free opening made into the trachea, immediately puts a stop to the vocal sounds, which, however, return on the opening being closed. An opening above the glottis, on the contrary, does not prevent the formation of the voice. Magendie has shown that the voice will continue, even if the epiglottis, the superior laryngeal ligaments, and the upper part of the arytenoid cartilages be injured; moreover, by forcing a current of air through the larynx in a dead subject, clear vocal sounds are produced, even after the removal of the upper ligaments, epiglottis, and upper portion of the arytenoids, provided, only, the vocal cords are made properly tense, and approximated.

It has been clearly proved by Miller, Willis, and others, that the vocal ligaments do not act either as vibrating strings, nor to the flute-pipe of an organ, but as *reed-instruments*, such as the clarionet, hautboy, &c. They cannot properly be compared to vibrating strings, since they are much too short to produce all the varied notes executed by the human voice, more especially the lower notes; moreover, their covering of moist mucous membrane would certainly prove an impediment to this mode of action. As regards their resemblance to a flute-pipe, it will be observed that in this the sound is produced by the vibration of a column of air contained in a tube, and the pitch of the note determined by the

length of the column, slightly modified by its diameter. The variety of tones of the human voice, cannot be explained on this supposition, since there is nothing in the form or dimensions of the current of air, between the larynx and mouth to warrant it.

In the reed-instruments we discover a much stronger analogy with the vocal apparatus. In these, a thin plate or lamina vibrates freely in a frame that allows the air to pass readily around it; a difference in the length of the reeds will produce a difference in the tone, as in the accordeon.

The *compass* of the voice in different individuals comprehends from one to three octaves; but the male and female voices commence and end at different parts of the musical scale; the lowest note of the female voice being about one octave higher than the lowest of the male voice; and the highest note of the female voice about an octave higher than that of the male. The entire scale of the human voice, male and female taken together, is about four octaves. The principal difference, therefore, between the two voices, is in their pitch; but they are also distinguished in their tone,—the female voice being softer. Two varieties, both of the male and female voice, are usually described; those of the male voice are technically termed the *bass* and *tenor;* those of the female voice, the *contr'alto* and *soprano.*

The mode of production of the *falsetto* notes is not very clearly understood. Müller attributed them to the vibrations of only the inner borders of the vocal cords. Petrequin and Dinday, on the other hand, believe that they do not result from the vocal cords at all, but from vibration of the air passing through the aperture of the glottis, which they think assumes at such times, the contour of the *embouchure* of a flute. Others again, suppose that in the falsetto notes, portions only of the vocal ligaments are made to vibrate, the rest remaining quiescent.

The will has the wonderful power of determining the exact tension of the vocal cords for the production of every variation of sound. It has been estimated by Müller that the difference in the length of the vocal ligaments between the states of tension and repose, in the male, is one-fifth of an inch; in the female, not

more than one-eighth of an inch. As the natural compass of the voice is about two octaves, or twenty-four semitones, and as a singer can produce at least ten distinct intervals within each semitone, there would be two hundred and forty distinct states of tension for the vocal cords, every one of which can be estimated by the will; and as the extreme variation in their length is only one-fifth of an inch, the variation required to pass from one state of tension to another, will only be the 1-1200th of an inch. This estimate is even lower than necessary for a practised vocalist. Madame Mara could sound fifty intervals between each semitone: the compass of her voice was at least forty semitones; hence, the variations were only the ten-thousandth of an inch.

The *pitch* of the voice is lower in males than in females, on account of the greater length in the vocal ligaments; but this difference does not arise till the period of puberty. The *timbre* or quality of the voice probably depends, in part at least, upon the degree of flexibility and smoothness of the cartilages of the larynx: thus, in women and children the voice is clear and smooth, and in them the cartilages are soft and yielding. The *loudness* of the voice depends a good deal upon the force with which the air is expelled from the lungs; but partly, also, upon the vibrations of the other parts of the larynx and neighbouring cavities increasing the resonance. *Song* depends upon the regulation of the vocal cords by the power of will, by which definite and sustained musical tones are produced. In man, the power of song is entirely acquired. In ordinary conversation, the voice is *modulated*, that is, passes through a variety of musical tones.

Articulate sounds or *speech*, are not produced in the larynx, but in the buccal cavity. A *whisper* is an articulate sound without any laryngeal tone; and all that is requisite to produce it is the propulsion of air through the mouth from behind forwards. Ordinary speech is a modification of the laryngeal tone by the mouth. The simplest form of speech is the sounding of the *vowels*, which are formed in the larynx, and are capable (with the exception of *i*), of being prolonged for any length of time. In pronouncing the *consonants*, there is more or less interruption of the

breath. These are so named because many of them cannot be properly sounded except *consonantly* with a vowel. These are divided into *continuous* and *explosive*, according as the breath is more or less completely stopped just before the pronunciation.

Stammering depends upon a want of control by the will, over the muscles of articulation, which are often spasmodically affected. There is considerable analogy between it and a local chorea; they are both increased by the excited emotions. The greatest difficulty of the stammerer consists in pronouncing the explosive consonants; the interruption of the breath which they occasion, being involuntarily continued beyond the proper time.

CHAPTER V.

THE PSYCHOLOGICAL ACTIONS, OR FUNCTIONS OF THE NERVOUS SYSTEM.

SECTION I.

GENERAL CONSIDERATIONS.

The composition and structure of the nervous tissue have already been treated of (Part III.) From what was there stated, it is evident that no nervous system can exist, unless the two forms of elementary nerve-matter be present—the *ganglia*, composed of vesicular substance, to originate power, and the *nerve-trunks*, composed of fibrous or tubular matter, to transmit the power.

All the various parts of the nervous system may be reduced to the two fundamental or elementary factors—a ganglion and a nerve; hence, in the lowest animal in which a rudimentary nervous system can be distinguished, it is found to consist of merely

these two elements. The nervous cords perform two offices; 1st, they are commissural, that is, they unite ganglia together so as to secure harmony of action; this is exemplified in the points of connexion between different parts of the brain, and also of the spinal centres; 2d, they convey impressions from sentient surfaces to ganglia, producing, if these reach the brain, *sensation;* or if they proceed merely to the spinal centres, *excitor* power; they also transmit power from the centres to the periphery, producing motion. According to the rule so frequently mentioned that every modification of function must depend on some modification of form, there must be some difference (though it is inappreciable to the senses), in the composition of the neurine of the different nerve-centres.

The possession of a nervous system has been generally deemed the peculiar point of distinction between animal and vegetative or organic life, since it is connected, not with the evolution of forms, but with the display of forces. Its phenomena may be comprised under the three heads of Spontaneous Movement, Sensibility, and Intelligence. These phenomena are not equally manifested in all animals, simply because the nervous system is not equally developed in them all. In the very lowest forms of animal life it is not possible to demonstrate the existence of a distinct nervous system; hence, those physiologists, who contend for the identity of vitality and nerve-life, and suppose that *none* of the acts of the living being can be performed without a nervous system, are forced to adopt the hypothesis of the existence of a "diffused" nervous system,—that is, the presence of nervous particles, in a separate form, incorporated with the tissues,—as a necessary alternative to a want of indication of its existence. Such certainly overlook the fact that even in the highest animals, all the organic, and some even of the animal functions, are performed without the necessary interference of the nervous system. Hence, it is not from the manifestations of *vitality* that we are led to infer the existence of a nervous system in these animals; but from their exhibiting evidences of *sensibility* and *spontaneous movement.* Such animals have been classified as the *Acrita;* they constitute the lowest tribe of the radiata.

The complexity of the functions of the nervous system is always proportionate to the degree of its development; thus, in the animals lowest in the scale (in whom a nerve-structure can at all be perceived), we find merely a ganglion with a nerve attached; and the only function performed is that of spontaneous motion,—the impression being transmitted from its exterior to the ganglion, and thence by a reflex power through the efferent fibres, exciting motion. A little higher in the scale, we have evidence of a distinct sensibility; and higher still, we find intelligence manifested, through the development of the brain.

Every class of animals has its own specific arrangement of the nervous system, affording a most rational basis for their classification. The arrangement of Cuvier embraced only the four classes of Radiata, Mollusca, Articulata, and Vertebrata. Prof. Owen's classification, now generally adopted by naturalists, distinctly recognises this principle. He divides the animal creation into the five following classes:—

1. *Acrita*, or such as do not exhibit very distinct demonstrable proof of a nervous system; it is consequently described as being in "a diffused state." In such animals there is no necessity for any special apparatus, since every part of it is brought into immediate contact with the nutritive fluid in which it lives. The spongia, monads, and the hydra are examples of this division. 2. *Nematoneura*, or those possessing a thread-like nervous system. This division corresponds with Cuvier's Radiata. The starfish and medusa afford good illustrations of this class. 3. *Heterogangliata*, or those in which the nervous system is destitute of symmetry in its arrangement; the ganglia are irregularly distributed throughout the body, being placed near certain organs. 4. *Homogangliata*, or those exhibiting a symmetrical nervous system. It corresponds with the Articulata of Cuvier. The ganglia are united upon a line. For each division, or ring, there is a corresponding ganglion, the largest being always at the head, and each acting independently of the others. 5. *Vertebrata*, or animals possessing a bony spinal covering. This class includes *reptiles*, *fishes*, *birds*, and *mammalia*. Like the preceding class, the gan-

glia are all connected together by commissures; but instead of being ventral, as in them, they are arranged along the back.

Our knowledge of the nervous system is derived from several sources,—as comparative anatomy and physiology, microscopic examinations, experiments—particularly vivisections, and pathological observations. The last are, generally speaking, most to be relied upon.

Comparative Structure of the Nervous System in different Animals.—The study of the comparative anatomy of the nervous system affords us an excellent method of unravelling this apparently complex portion of the animal organism. The condition of this system in the very lowest of the Radiata (the *Acrita*), has already been noticed. In the higher radiata, as the *star-fish*, the mouth is surrounded by a filamentous ring, which presents a regular series of ganglionic enlargements, one of them corresponding to each of the segments of the body, and each sending a branch to the corresponding ray, and two smaller ones to the viscera within the central disk.

In the Mollusca, which are characterized by the great predominance of the nutritive system over that of animal life, the nervous system generally bears but a small proportion to the whole mass of the body. The part that is chiefly developed is that which presides over the special functions; thus in the higher mollusks there are at least three ganglia:—the *bronchial* or respiratory, the *pedal* or locomotive, and the *cephalic* ganglion, which is the centre of its sensations. Frequently we find other special ganglia superadded.

The Articulata are the reverse of the mollusca, being characterized by great muscular development and energy of movement; and in them the nervous system is almost entirely subservient to this function. It consists usually of a chain of ganglia, connected by a double cord extending from the head through the body. Each ganglion is double,—one half for each side; and one ganglion is generally appropriated to each segment of the body, which it supplies with nerves. In some cases, the number of these segments amounts to several hundred, and the number of ganglia equally increases. Each segment is a perfect representation of the others,

but is entirely independent of its fellows, as may easily be shown by cutting up a centipede or earth-worm into any number of pieces, every segment exhibiting motion when irritated, through *reflex* action. The *cephalic* ganglia are always the largest: they are connected with the organs of special sense. From the numerous observations and experiments upon the articulata, it would appear that the ordinary movements of the legs and wings are of a reflex character, though harmonized and directed by their instinct, or will, which acts through the cephalic ganglia. It also appears, that although this class of animals are chiefly remarkable for their *instinct* (as witnessed in the bee), still, their actions are of a *consensual*, rather than of a *rational* character.

In the Vertebrata the nervous system differs from that of the foregoing classes in two important particulars: in the latter it appears only to be an appendage to the rest of the system; in the former the whole structure seems to be subservient to it, and designed to carry out its purposes. Again, the vertebrata possess a complete bony casing for the protection and support of the nervous system, while no such special provision exists in the Invertebrata. In the vertebrata, the nervous systems of both the mollusca and articulata appear to be united, since they combine the *sensory* powers of the one, with the *locomotive* powers of the other. But there are also parts superadded, which are not found in either of the others: these are the cerebellum and the cerebrum, which are superimposed, as it were, upon the cephalic ganglia of the others, the latter being only connected with the organs of special sense. Again, we find the different locomotive ganglia united together in one continuous cord—the *spinal marrow*, though the independence of each is still preserved. The upper portion of the spinal cord, which is prolonged into the cranium so as to be in immediate relation with the encephalon, is termed the *medulla oblongata*, and is the centre of the respiratory and stomato-gastric nerves. The visceral or sympathetic system of nerves also assumes a more distinct form; but its ganglia are not, for the most part, protected, as the others, since they lie in the cavity of the trunk.

It is then only in the higher vertebrata and man, that we can clearly perceive the two great divisions of the nervous system—the *cerebro-spinal*, and the *sympathetic* or *ganglionic*. The former includes the brain, spinal marrow, and special nervous centres; together with the nerves proceeding from them to the different parts of the system: they preside over volition, sensation, excito-motor, or reflex action, and the intellectual phenomena. The latter comprises a chain of ganglia, placed on each side of the vertebral column, extending from the base of the cranium to the os coccygis. Its function is difficult to determine, from its absence in the lower animals,—being in these replaced by the pneumogastric nerve; but from its branches chiefly supplying the organs of organic life, and from its communicating with the spinal and cephalic nerves, it is inferred that its office is to bring the functions of organic life into sympathy or relation with those of animal life.

As regards the *mode* in which the different parts of the nervous system perform their functions, we are altogether ignorant. We can only witness the phenomena; the *causes* are, thus far, purely conjectural. It is well understood, for example, that the functional activity of the nervous system is intimately connected with a due supply of oxygenated blood,—oxygen appearing to be the normal excitor of the nerve-force. Again, the activity of function appears always to be evidenced by the amount of molecular disintegration,—doubtless, through the increased agency of oxygen, as shown by the increase of the phosphatic deposits in the urine, after prolonged or very active mental exertion. As regards the method by which impressions are propagated to, or motor power from, a nervous centre, there undoubtedly is a strong analogy with the transfer of electricity along a wire; and most probably, like the latter force, the nerve-force may be dependent on, or connected with, some molecular disturbance in the conducting fibres, or in the ganglionic centres. The reasons for not considering it *identical* with electricity have already been pointed out, when treating of Electrical Phenomena.

We next proceed to give a condensed description of the structure and functions of the different parts of the Nervous System.

SECTION II.

THE CEREBRO-SPINAL AXIS.

THE Cerebro-Spinal Axis consists of the brain, medulla oblongata, and spinal marrow; including, also, the afferent and efferent nerves connected with their centres. These will be treated of separately.

THE SPINAL MARROW.—The spinal cord was formerly regarded as a mere bundle of nerves proceeding from the brain, and quite subordinate to it; but it is now well ascertained to be a distinct nervous centre, and to be of far greater importance to organic life than the brain itself, since an animal can live even if deprived entirely of its brain, which it cannot do, if the spinal marrow, including the medulla oblongata, is destroyed. It is also known that the functions of the spinal cord are independent of, and often opposed to, the will; and that its actions are of a *reflex* character,—that is, the motor impulses which originate in it are not spontaneous, but are the result of impressions made on it by the afferent trunks, and without the necessity of intervention of sensation.

The spinal cord is bilateral, being composed of two distinct halves united together in the middle by commissural fibres. This union is much closer in man and mammalia than in the lower vertebrata, but the division is still marked by a deep anterior fissure and a shallower posterior one. There are also two lateral fissures on each side: so that each half is divided into an *anterior*, *middle*, and *posterior* column. The gray or cineritious matter is on the interior, and the medullary matter on the exterior. If a transverse section be made, the gray matter is seen in the form of two crescentic patches, the points of each crescent being directed towards the lateral fissures of each side, and the convexities approaching very near each other, and connected together by a transverse band of gray matter. The relative portions of white and gray matter vary in different parts of the cord. In the cer-

vical region there is an increase of gray matter corresponding with the origin of the brachial plexus; there is a still greater increase of the gray matter in the lumbar region, corresponding with the origin of the nerves of the lower extremities. In many of the lower animals, the same variation is observed, the increase of the gray matter being always well marked at those points of the spinal cord where there is a great amount of power to be supplied: thus, in the flying-fish, it is seen where the pectoral fins are supplied: in birds of active flight, the enlargement occurs opposite the wings; and in birds of great locomotive powers, as the ostrich, it is most evident in the posterior ganglia. Hence the inference, that the increase of the gray matter of the spinal cord is, in some way, connected with the amount of *power* to be supplied.

The spinal cord may also be considered as composed of thirty-one or thirty-two separate sections, from each one of which two pair of spinal nerves proceed,—one pair for each side. There can be no question, from pathological observations, that each spinal section is double, being completely divided by the anterior and posterior fissures; evidence of this independence of function is afforded by cases of spinal palsy, in which one side only may be affected. In the *homogangliata*, as we have seen, the ventral cord is actually double; and although in the higher vertebrata the two halves are more or less fused into one, still the anterior and posterior fissures very nearly divide them. The transverse commissure of medullary matter passing between the two halves serves to harmonize the actions of both.

The roots of the spinal nerves all consist of an anterior and posterior fasciculus; and the functions are quite different. It is proved by experiment, that the *posterior* roots are made up of afferent fibres, and only convey impressions towards the nervous centres; these impressions, if confined to the cord itself, excite *reflex* action; but if conveyed to the brain, they produce *sensations*. Again, it is equally certain that the anterior roots are made up of efferent fibres, which convey, from the nervous centres, motor power to the muscles. If the impulse comes from the cord only, the movement is entirely *reflex*; if from the brain, it is *voluntary*.

On this view, then, each spinal nerve consists of *four* sets of fibres, as follows: 1st. A *sensory* bundle, passing upwards to the brain. 2d. A set of *excitor* or *afferent* fibres, conveying impressions to the spinal cord. 3d. A *motor* set, conveying the influence of volition and emotion downwards, *from* the brain. 4th. A *motor* or *efferent* set, conveying motor power from the spinal cord. Of these, the first and second are united in the *posterior* roots; the third and fourth in the *anterior* roots.

The roots of the spinal nerves can be traced into the gray matter; and it is highly probable that many filaments also connect with the medullary portion of the cord, and are by this means united with the brain.

The gray or vesicular column of neurine, situated near the centre of the spinal cord, is the originator of the nerve, force proceeding from the cord, and the recipient of the excitor impressions conveyed to it. Its double crescentic shape has already been alluded to. Posteriorly, its processes or cornua almost extend to the surface at the so-called lateral fissure; here it is that the posterior roots of the spinal nerves take their origin. The anterior roots penetrate downwards, to reach (as is believed) the gray neurine, which lies much deeper than posteriorly; they have not, however, been distinctly traced to it. The anterior and posterior roots are distinguished by the ganglion existing upon each of the latter.

The medullary or white matter of the cord may be physiologically divided into four columns,—*two posterior*, extending from the posterior fissure to the posterior horns of the gray neurine, and *two anterior*, extending from the anterior fissure to the anterior roots of the spinal nerves. The posterior columns are very nearly of the same size throughout; at the medulla oblongata they gradually are merged into the cerebellum, which, by means of this connexion, exercises a control over it. From the cerebellum they proceed on to the nucleus of the brain. They may be very properly regarded as truly *commissural* in their function, connecting the different posterior spinal centres with the medulla oblongata, cerebellum, thalamus and corpora striata. It

will be remembered that no nervous filaments connect with these medullary columns, since the posterior roots terminate in the gray matter.

The anterior, or antero-lateral columns are, in like manner, to be traced into the anterior columns of the medulla oblongata, the cerebellum, and the cerebrum.

As regards the *mode* in which the influence of the brain is extended to these columns of the cord, the explanation usually given is, that, for a sensory impression to be conveyed through the posterior spinal nerves, these must continue their upward course after entering the spinal marrow, until they terminate in the brain; also, that the influence of volition is transmitted in like manner from the brain downwards, through fibres which pass into the anterior spinal nerves. There is an obvious difficulty in admitting this explanation, which considers a large part of the spinal cord as composed of cerebral nerves; if it were true, we should expect to find their columns much larger above than below, on account of greater accession of nerve-fibres; this, however, as is well known, is not the case. It is more probable that each spinal nerve *terminates* in its own centre, and that it proceeds no farther; but that all the different centres are united by commissures. These views of the *commissural* functions of the medullary columns of the spinal cord are advocated by Messrs. Todd and Bowman, and other eminent physiologists.

Another most important function of the spinal cord remains to be considered—that of *reflex* or *excito-motor action*. By this term is understood its inherent power of producing muscular movements, on receiving impressions through its afferent nerves, and that, entirely independent of either sensation or volition. The peculiar arrangement of the nervous system in the articulata, very clearly demonstrates the mode in which it is produced. In this class of animals, each one of the numerous ganglia is perfectly distinct and independent of its fellows; it regulates only those parts of the body which are supplied by the nerves passing on either side from that centre. Now, if one of these lower animals—a centipede for example—be divided into segments,

movements may be excited in any one of them by a slight irritation; here, there certainly could not have been any sensation, since there was an entire separation from the cerebral ganglia. By dividing the spinal cord in the lower animals, sensation will of course be destroyed; but if the posterior or afferent roots of the nerves be irritated, motion immediately ensues: if, now, the anterior roots be divided, no motion can be excited. Where the spinal marrow is whole, and the brain has been removed, an irritation made in any part of the surface, will produce motion, even in distant parts. This is frequently exhibited, as a pathological condition, in the highest animals, and even in man, as witnessed in the convulsions which are so often the result of some local irritation.

The *adaptiveness* of reflex movements is no proof of the existence either of the consciousness or will of the being which executes them. The adaptation is made *for* the being—not *by* it; and it arises from the law impressed upon the nervous system, by means of which a certain movement adapted to produce a certain effect is executed by a certain impression.

Although the action of the spinal cord is not necessarily dependent upon any other portion of the nervous system than its own centres, it may nevertheless be called into action in various ways, —as by the *will*, through the anterior commissural fibres of the cord; by the *emotions* and *passions*, acting often entirely independently of the will; and by a power controlling the *automatic* movements of the body.

The particular reflex actions governed by the spinal cord, have chiefly reference to the *organic* functions. They are, for the most part, of an *expulsive* kind, as defecation, urination, parturition, and the ejaculatio seminis. Over the two former the will has some control, so long as the stimulus is not very violent; but not over the two latter, when once the stimulus has come into action. The movements of the lower extremities seem also, in a great measure, governed by reflex action. This is particularly seen when the influence of the brain is suspended, so as to destroy the power of the will; then the slightest stimulus, such as tickling the sole of

the foot, will produce decided movements in the limb. It is very probable that much of locomotion in man is produced by reflex action, after it has once been commenced by an effort of the will. It is certain that birds can continue their flight, when deprived of their cerebrum.

The reflex action of the spinal cord is often of an abnormal or pathological character. *Convulsion* and *spasm* are the most common disorders connected with it and the medulla oblongata. Convulsion differs from spasm in being attended with a loss of consciousness; it consequently must involve also the medulla oblongata and cerebral lobes; in convulsion, the respiratory actions are nearly always affected. Three forms of convulsive diseases are noticed:—1. They may be simply *reflex*, resulting from some unusual irritation on any sentient surface, as the stomach or bowels, or gums,—as in the teething of children. 2. They may be merely *centric*, that is, resulting from a peculiar condition of the spinal centres, which occasions muscular movement without stimulation. 3. They may depend upon both causes combined,—the nervous centres becoming very irritable, and susceptible to the slightest irritations, which would commonly be harmless. This last class is the most common, as seen in the convulsions caused by teething, intestinal worms, and irritable matters in the stomach and bowels,—the convulsions ceasing when the irritation is removed. Instances of the *centric* form of convulsion are afforded in hydrophobia, tetanus, epilepsy and hysteria. In *hydrophobia* the medulla oblongata and the ganglia of special sense are likewise involved,—their peculiar condition being the result of a virus introduced into the blood; the brain entirely escapes. When once the centres are excited, the slightest stimulus will produce the most violent spasms. The stimuli which display the most powerful influence are those which act through the senses, as sound, sight, and taste. *Tetanus* is a very similar affection, only the ganglia of special sense are not involved. It may originate entirely in the nerve-centres, as in the idiopathic form; or it may arise from an external irritation, as a lacerated wound, constituting the *traumatic* form. The injured nerve transmits the irritation to the nervous centres and sets up an excita-

ble state in them. Hence it is, that the removal of the original source of irritation rarely proves beneficial, because the nerve-centres being now affected, the spasm will be excited by the slightest irritation. *Epilepsy* consists of convulsions attended with temporary suspension of the functions of the brain. It also may result from local irritation, as teething, and will cease on the removal of the cause; but when confirmed, the nervous centres become diseased, and no treatment appears to do good. These diseases prove fatal by the suspension of respiration, through spasm of the respiratory muscles. *Hysteria* may imitate all the others; but in it there does not seem to be any fixed disease, so much as a peculiar *general* nervous excitability. It is often relieved by mild remedies. Sometimes it appears due to a local irritation, as of the uterus.

There are some other convulsive diseases of a more local nature, dependent upon reflex action, as spasmodic asthma, which is often due to irritation of the lungs or digestive organs. Spasmodic croup often arises from the irritation of teething, or of undigested food in the stomach and bowels, producing contraction of the constrictors of the larynx. Choking results more from the spasm of the larynx, than from the pressure of the morsel upon the air passages. Tenesmus and strangury are both instances of spasm through reflex action. Abortion appears sometimes to be produced in the same manner.—The spinal cord is likewise the great centre of the dynamic forces of the economy. These have been previously explained. The two pathological conditions to which they are liable are *hyperdynamia* or excess of force, exhibiting itself in spasms, and *adynamia* or loss of force, displaying itself in excessive prostration or fatigue on the slightest exertion, or in complete paralysis.

THE MEDULLA OBLONGATA.—The Medulla Oblongata is the cranial prolongation of the spinal cord; it is also the medium by which the different fibres of the spinal cord are connected with the brain. Like the cord, its function is that of reflex action. Each lateral half comprises four divisions, namely, the *anterior pyramid*, the *olivary body*, the *restiform body*, and the *posterior pyramid*. Their connexions are as follows:—

The anterior pyramids connect the antero-lateral columns of the spinal cord with the *motor* fibres of the cerebrum. A large number of their fibres decussate; those coming from the right hemisphere passing into the left side of the cord, and *vice versâ*,—an arrangement which accounts for the fact that in hemiplegia, the paralysis is on the side of the body *opposite* to the lesion of the brain. The fibres of the anterior pyramids, in their ascending course, chiefly enter the crura cerebri, passing through the pons varolii, and traversing the optic thalami; then they diverge, and become mingled with gray matter, thus forming the corpora striata, and finally radiate into the convolutions of the brain. The non-decussating fibres pass downwards, along with fibres of the olivary bodies, into the anterior column of the cord. The decussating fibres pass to the middle column of the cord. Hence the anterior pyramids may be regarded as *commissures* between the brain and anterior spinal centres, or those of muscular movements.

The corpora olivaria are composed externally of fibrous matter. In their upward course, part of them proceed forwards to join the crus cerebri, and part backwards, into the corpora quadrigemina. In their course downwards, the fibres converge, so as to form the greater part of the anterior column of the cord. Beneath the fibrous layer is a mass of gray matter called *corpus dentatum*, continuous with the gray matter both above and below. Mr. Solly supposes the olivary bodies to be the ganglionic centre of *speech*. They are probably the true respiratory ganglia.

The corpora restiformia pass above into the hemispheres of the cerebellum; below, chiefly into the posterior columns of the cord; but a band of *arciform* fibres crosses over to the anterior columns.

The posterior pyramids are on each side of the posterior median furrow. Their upward course is, by some, supposed to be through the crura cerebri into the thalami, and so on to the convolutions; by others, they are thought to stop short at the fourth ventricle. Below, they contribute to form the posterior column of the spinal cord.

The two important functions of a reflex nature performed by the medulla oblongata are *respiration* and *deglutition*. In all

respects, it acts just like any segment of the spinal cord, although it *seems* to possess a distinctive character from the mere importance of the functions that it executes. The chief *excitor* nerve in respiration is the par vagum; but the afferent portion of the fifth pair is a strong excitor, as are also the afferent portions of all the spinal nerves conveying impressions from the general surface. The chief *motor* nerves are the phrenic and the intercostals, which probably originate in the medulla oblongata; likewise the motor portions of the par vagum, the facial, and the spinal accessory. The ordinary movements of respiration are performed through the phrenic and intercostals. The will also has some influence over the functions of respiration.

The function of *deglutition* is of a purely reflex character. No mere effort of the will can either produce or prevent it. When once the morsel is within the grasp of the constrictor muscles of the pharynx, we cannot avoid *swallowing.* The chief *excitor* nerve is the afferent portion of the glosso-pharyngeal, assisted by the branches of the fifth pair distributed upon the fauces, and the superior laryngeal, distributed upon the pharynx. The chief *motor* nerves are the pharyngeal branches of the par vagum, together with the hypoglossal, the facial, the motor portion of the fifth, and the motor portions of some of the cervical nerves.

The acts of prehension and mastication, along with sucking, are usually voluntary in the adult. Sometimes they are reflex, as in the case of the infant. The act of *suction* is also reflex in a state of coma.

In the propulsion of food down the œsophagus, so far as the muscular contraction is of a reflex character, its *excitor* nerves must be the œsophageal branches of the par vagum; the *motor* power being derived from the efferent portions of the same branches. The same is probably true of the movements of the stomach; though it is believed that the peristaltic movements of the whole alimentary canal are excited, independently of the nervous system, by *direct* irritation. There are other reflex actions of the medulla oblongata connected with the closing of the glottis, and of the pupil of the eye, which are noticed elsewhere.

The medulla oblongata is also believed to be the centre of the

co-ordinating or harmonizing power for the involuntary and instinctive movements—particularly those of respiration.

The Encephalic or Sensory Ganglia.—The *sensory ganglia* are ganglionic masses lying at the base of the brain, which seem to be the centres of the nerves both of special and general sensation. In the invertebrata we find the *cephalic* ganglia, which are to be regarded chiefly as *optic* ganglia. In fishes we find the *olfactive*, *optic*, and *auditory* ganglia well developed. In man, and the higher mammals, these ganglia of special sense are much smaller in proportion to the whole encephalon; but still they can be made out. Thus the bulbous expansions of the olfactory nerves are the *olfactive ganglia*, since they contain gray or vesicular substance; and their trunks, which connect them with the brain, have their analogy in many fishes. The olfactive ganglia are more evident in those mammalia whose powers of smell are strong.

The *auditory ganglia* are most distinct in certain fishes. In higher animals and in man, the auditory nerve may be traced to small masses of gray matter which lie on each side of the fourth ventricle. No very distinct *gustatory ganglion* can be made out, as the sense of taste may be considered as a modification of that of touch. Stilling regards a collection of gray matter imbedded in the medulla oblongata as the nucleus of the glosso-pharyngeal nerve, and to which also a portion of the sensory root of the fifth pair may be traced.

In tracing the medulla oblongata upwards, it is found to be connected with very conspicuous gangliform bodies—the *Pons Varolii*, *Corpora Striata*, *Tubercula Quadrigemina*, and *Optic Thalami*.

The *pons varolii* is a large protuberance placed between the medulla oblongata and the crura cerebri. Its medullary fibres pass in various directions, and are intermingled with scattered gray neurine. These fibres are distinctly commissural; they accompany others from the medulla oblongata into the cerebellum. The transverse fibres pass from one side of the cerebellum to the other. Nothing very definite is known of the functions of the pons; mutilations of it, reaching to its centre, are stated to be

accompanied with a loss of muscular power. If the injury be confined to one side, there is no loss of involuntary motion, but a want of co-ordination over the voluntary movements, as in injuries of the cerebellum.

The *corpora striata* and *optic thalami*, although intimately connected with the cerebral hemispheres, are also very closely united with the medulla oblongata,—the corpora striata with the anterior pyramids, and the optic thalami with the olivary bodies. As only *motor* impressions are conveyed along the anterior columns of the spinal cord, the corpora striata, into which these columns merge, may be regarded as the centre of volition, or of voluntary movements. If the corpora striata be destroyed, the animal loses the power of avoiding objects placed in his way.

In like manner, as *sensory* impressions are exclusively transmitted upwards through the posterior columns to the olivary bodies, the thalami optici are generally regarded as the centres of common sensation; they stand apparently in precisely the same relation to the common sensory nerves which convey impressions from the periphery of the body, as the optic and other special ganglia do to their nerves of special sense.

The *tubercula quadrigemina* represent the *optic ganglia*. To these, the principal parts of the optic nerves can be traced. In man, they are much smaller than in the lower mammalia. They are the true centres of vision, and also preside over the motor nerves of the eye. In the lower vertebrata, they appear to be the centres of the *instinctive* movements of the eye, by a reflex action. In man, they probably constitute the centres of the *consensual* or *harmonious* movements of the eye, by virtue of which the two axes are made to converge upon the same object. The action is *emotional*, and bears a strong resemblance to the instinctive movements of the lower animals.

The *crura cerebri* are also commissural; there are thick, medullary cords connecting the anterior pyramids of the medulla oblongata, with the corpora striata. They contain the *locus niger*—a very dark ganglionic mass, regarded as the centre of the third

pair, which are chiefly concerned in the movements of the eye and iris.

The above five prominences at the base of the brain, together with the medulla oblongata, constitute what M. Foville denominates the *nucleus of the brain.* This, along with the spinal axis, may be regarded as composing one single nervous system, entirely irrespective of the brain. Comparative anatomy proves that these parts are always the first to be developed in the nervous system. They are concerned in the conservative actions of the economy.

The *muscular sense,* or that by which we are made sensible of the *tone* of the muscles, appears to be different from common sensation; it probably has its centre in the sensory ganglia at the base of the brain. A good example of the delicacy of this sense is seen in the regulation of the muscles of the voice in singing. The emotional or instinctive acts differ from purely reflex acts, by the necessity existing in all cases, of sensation. The emotional acts evidently differ also from the voluntary acts, from the fact that often the muscles influenced by the one may be paralysed, while they remain responsive to the power of the others. *Tickling* is an instance of an emotional act, which, like the others, always requires sensation. *Hysteria* is an example of an excited state of the emotional system: a paroxysm is often brought on by causes producing certain sensations or emotions,—as the mere sight of another person suffering from an attack. In this way, many of the movements of mesmeric patients may be accounted for, as being of an emotional character, and excited by any powerful feeling, as a strong desire to gratify an audience, &c.

THE CEREBELLUM.—All vertebrated animals have a cerebellum, though in some it is extremely small, being a mere appendage to the medulla oblongata. The most important part of it seems to be the centre, or *vermiform process.*

The cerebellum consists of the two species of neurine, arranged in a peculiar manner, so as to give it the *arbor vitæ* appearance. By its three separate portions it is placed in relationship with all the parts of the nervous system hitherto considered, but not with the convolutions of the brain. Its function seems in some way

connected with *motion*, and chiefly with variety and activity of movement, since it is always very large in animals remarkable for active and varied movement, as the swallow, the shark, the semi-erect ape, and especially in man. Experiments go to prove that it is neither connected with sensation, volition, or reflex movements, but with the power of *associating* or *combining* various movements, as in walking, leaping, standing, or keeping the equilibrium. Pathology exhibits the same facts;—thus a chronic lesion of the cerebellum seldom affects the motor functions, while it causes a want of power to harmonize the movements. An injury done to the cerebellum of animals, causes them to stagger in their gait, and to lose the power of balancing themselves. So also when inflammation is confined to the membrane of the cerebellum, it does not produce delirium. Sudden effusions into the cerebellum, as in any other part of the encephalon, will occasion paralysis or apoplexy. There appears sufficient reason, then, to regard the cerebellum as the great co-ordinating centre for the *voluntary* movements, just as the medulla oblongata is, for the respiratory movements. The loss of this harmonizing power is particularly well seen in *chorea*. Some ascribe the *muscular sense* to the cerebellum, from the fact that pain is produced by wounding the crura cerebelli.

The phrenological idea that the cerebellum is the seat of *sexual instinct* is without due foundation, since comparative anatomy shows a want of correspondence between the size of the cerebellum and the power of the instinct in different animals: thus it was found actually larger in geldings than in stallions or mares. Neither does pathology support the views of Gall, since the supposed connexion between disease of the cerebellum and excitement of the genital organs may be produced equally well by excitement of the spinal cord and medulla oblongata. It is possible that the cerebellum may be the seat of both functions, and that the excessive exercise of the one should diminish its power with regard to the other,—since it is known that great muscular exercise will diminish the sexual feelings, and *vice versâ*.

THE CEREBRUM.—The cerebrum is the organ of *intelligence*, or

the voluntary adaptation of means to ends, so as to imply a perception of both. Intelligence is also estimated by the degree of *educability.* None of the invertebrata have a cerebrum, although some of the insects, as the bee, display a remarkable degree of *instinct.* The cerebral hemispheres may be removed, and the animal not only live, but perform all the essential *organic* functions, as deglutition, suction, respiration, &c.: it also retains the power of equilibrium. The relative amount of intelligence in different animals corresponds closely with the relative development of the cerebrum. But this development does not so much depend upon the size of the cerebrum, as upon the number and complexity of the convolutions, by which the amount of *gray* matter is augmented; and as we advance from the lower to the higher animals, there is also an increase in the commissural fibres. In infancy the convolutions are imperfectly developed; if their growth be arrested there is but feeble mental power. In idiots they are very limited.

The largest commissure of the brain is the *corpus callosum,* which unites the two hemispheres. Its fibres can be traced into the hemisphere of each side, particularly at their lower part; and they probably radiate, along with the fibres from the thalami and corpora striata, to the surface of the hemispheres. The corpus callosum is wanting in fishes, reptiles, and birds; and it is either very incomplete, or wanting, in some of the mammals with least perfect brains. The *anterior commissure* unites the two corpora striata; but many of its fibres pass through these bodies, to radiate upon the middle lobes. This commissure is particularly large where the corpus callosum is deficient. The *posterior commissure* unites the two optic thalami. Besides these, there are other commissural fibres, as the *pons tarini, tuber cinereum,* and the *soft commissure.* There are also *longitudinal* commissures uniting the anterior and posterior parts of the hemispheres, of which the largest is the *fornix,* situated beneath the corpus callosum.

The brain is abundantly supplied with blood by the carotids and vertebrals; these have a very tortuous course, in order to avoid the effects of too strong an impulse upon the delicate organ.

There is no direct communication between the cerebrum and cere-

bellum, the only commissure being the *processus a cerebello ad testes*, which passes onwards through the tubercula quadrigemina to the thalamus of either side. This alone would suggest the idea of the entire difference of their functions. We learn very little by experiments, of the functions of the different parts of the cerebrum, or of the ganglionic masses connected with it. No pain is experienced even if the whole hemispheres are removed, slice by slice; nor do convulsions ensue, either from the above experiment, or when the corpora striata or thalami are wounded. But if the tubercula quadrigemina are involved, convulsions arise. The same is true with regard to man, as far as has been observed. In cases where part of the brain has protruded and has been removed, the operation was attended with no pain, although the mental powers were perfect. Hence, the cerebrum seems to resemble the nerves of special sense, in not being sensible to ordinary impressions. Pressure on the brain produces a suspension of all its powers, causing entire loss of consciousness, like profound sleep.

Experiment has revealed nothing certain as respects the function of the corpus callosum and other commissures. But it would seem that many cases of idiocy were connected with a partial or entire absence of these parts; reducing the cerebrum to the condition of that of the lower mammalia.

Pathology affords but little insight into the functions of the cerebrum. Severe lesion may exist in one hemisphere without any interference with the mental operations; but this is not the case when both hemispheres are involved. A sudden lesion, though comparatively trifling, will produce more severe symptoms than one much more extensive, if of a chronic nature. Thus, a sudden paralysis producing death, may result from a slight effusion in the substance of the corpora striata; but if the paralysis has followed some chronic central disorder, a much greater amount of lesion will usually be met with. In profound sleep, the cerebral functions seem to be entirely dormant; though the spinal system, on which reflex action depends, is in a state of activity. The sensory ganglia also appear to be inactive in deep sleep; but where it is less profound, certain *consensual* acts are performed,

which require sensation without reflection or memory,—such as turning in bed when the position becomes uneasy, or where we give some sign of recognition when our names are called. The latter is rather an *automatic* act, and resembles those acts which are performed when in a revery, in which, by frequent recurrence, certain movements are directly excited by the sensation, without the intervention of the will, which formerly was necessary. In cases of coma, or narcotic poisoning, &c., we have the same gradations as in sleep. When it is not very profound, the cerebral hemispheres seem alone to be affected; when complete, however, the sensory ganglia also are involved, and only reflex actions are performed; and if it becomes fatal, the torpor extends to the medulla oblongata, producing loss of the power of deglutition and respiration. In *dreaming*, the cerebrum appears to be partially active: sensations seem to suggest a train of thought, which, however, is not controlled by the mind. In *somnambulism*, the brain is in a still more active state, being readily affected through any of the senses, except sight. There is also a remarkable power of *balancing*, and of combining movements, which indicates great activity of the cerebellum.

The faculty of *memory* resides entirely in the cerebrum. This faculty forms one of the first conditions to the reasoning process, since, without it, we must be destitute of *experience*. It is possible, if not probable, that no impression made upon the brain is ever entirely lost, except through disease; but it may be beyond the power of the will to recall it. It seems to depend upon the power of *association;* and a long time may elapse before the same combination of ideas and circumstances may again occur. Sometimes it takes place in delirium, or dreaming; and ideas are recalled, of which the mind in its healthy state had no remembrance.

As regards the views of Phrenologists, although it is not improbable that different parts of the brain should be the seats of different faculties of the mind, still, the subject is far from being settled. Nor are their views so supported by comparative anatomy, as to remove many objections.

In connexion with the cerebro-spinal axis, the functions of the Cephalic and of the Sympathetic nerves may also be considered.

THE CEPHALIC NERVES.—Neither the olfactive, optic, nor auditory nerves are at all endowed with common sensibility, but are solely nerves of *special* sense. They may be cut, pinched, stretched, &c., without causing any sense of pain. The common sensibility of the parts supplied by them is due to the branches of the fifth. The common sensibility may be lost, while the special sensibility remains, and *vice versâ.* No reflex movement can be excited in the olfactive nerve, and the only reflex movement of the optic nerve is that affecting the size of the pupil, and probably the closing of the orbicularis muscle. In the same way, it is probable that the tension of the membrana tympani may be effected by reflex action through the auditory nerve, by means of the facial nerve.

The *decussation* of the optic nerve is complete in those animals whose eyes have different spheres of vision; but in man, and in animals whose eyes look in the same direction, the decussation is incomplete. The true optic nerve (which occupies the middle portion of the optic chiasm, and is distinct from its anterior and posterior commissural fibres) is composed of two tracts,—an *external,* which passes directly outwards to the eye of that side, and an *internal,* which crosses over to the eye of the opposite side. The distribution upon the retinæ is such, that the fibres from either optic ganglion proceed to *its own side* of *both* eyes: that is, the right optic ganglion is exclusively connected with the outer portion of the right retina, and the inner portion of the left retina; whilst the left optic ganglion is, in like manner, connected exclusively with the outer portion of the left retina, and with the inner side of the right. (Mayo.) From this it follows that each optic ganglion receives the sensations of objects on the *opposite* sides of the body. The intention of it may be to bring the visual impressions into proper harmony with the motor apparatus; so that the decussation of the motor fibres of the pyramids is neutralized by the decussation of the optic nerves.

The third, fourth, and sixth nerves are the motor nerves of the

orbit. The *third* (oculo-motor) is distributed to all the muscles of the eye, except the external rectus, and superior oblique. Its function is chiefly motor; and it is probable that the slight sensibility which it exhibits under irritation is due to anastomosis with the branches of the fifth. Some of the muscular movements caused by the third nerve are purely voluntary, as those of the levator palpebræ, and the external rectus; others again are reflex or instinctive, as those which are directed by the inferior branch of the third, such as the contraction of the pupil, and the movements of the inferior oblique muscle. The *fourth* nerve is distributed to the superior oblique exclusively,—it is named *patheticus*, from the idea that it causes the upward and inward motion of the eye. Its real function is the reverse; the upward and inward movement is due to the inferior oblique muscle. The *sixth* nerve (abducens) is distributed solely to the rectus externus muscle, which moves the eye outwards. Both the fourth and sixth nerves are *voluntary*.

The *fifth* (trifacial) has two distinct roots, on the larger of which is a ganglion. The fibres of the smaller root do not blend with the others, till the latter have passed through this ganglion; and it can be shown by dissection, that they only pass into the inferior maxillary division of the nerve: the ophthalmic and superior maxillary branches, being almost entirely spent upon the skin and mucous surfaces, are nerves of sensation; whilst the inferior maxillary branch largely supplies the muscles, and is, consequently, both a motor and sensory nerve. If the main nerve be divided within the cranium, the animal evinces signs of pain, and the sensibility of the part supplied by the nerve is destroyed. If both trunks be divided, the whole head is deprived of sensibility. If the ophthalmic branch only be divided, then the parts supplied by it lose their sensibility, but not their powers of motion; the pupil is sometimes contracted, and sometimes dilated; and the eyeball speedily inflames and suppurates, from a want of the natural secretion. The division of the superior maxillary branch is also attended with a loss of sensibility, but not of motion. The different subdivisions of the inferior maxillary have both sensory

and motor powers, in different degrees. The lingual branch seems to be chiefly sensory.

The portio dura of the seventh is the *facial nerve.* If exposed within the cranium, it exhibits only motor powers. Afterwards, it becomes partly sensory, from anastomosing with other nerves, as branches of the fifth and of the cervical nerves. The portio dura is the motor nerve of the face, and is governed both by volition and the emotions; it is also the channel of the reflex movements concerned in respiration. Its *voluntary* power may be lost, while its *emotional* or *reflex* power may be unaffected, and *vice versâ.*

The general functions of the *glosso-pharyngeal* are those of an afferent nerve, conveying impressions to the medulla oblongata, which produce reflex movements through other nerves. It is chiefly distributed to the mucous surface of the fauces and back of the tongue, and it also sends a branch forwards, to supply the edges and inferior surface of the tip of the tongue. It and the lingual are together concerned in the sense of Taste; but the glosso-pharyngeal is believed to be the channel through which disagreeable impressions made on the mouth excite nausea and attempts to vomit.

The *par vagum*, or pneumogastric arises from the medulla oblongata, and is spent upon the pharynx, larynx, trachea, lungs, heart, and stomach. Valentin has discovered that, at its roots, it possesses no motor power, but that after its inosculation with the spinal accessory, it exhibits motor powers. The great function of its *afferent* fibres is to convey to the medulla oblongata the impression produced by the venous blood upon the capillaries of the lungs, or of carbonic acid in the air-cells. It also conveys impressions from the larynx, trachea, and bronchi, as well as from the œsophagus and stomach. The effect of dividing the par vagum of *one side* is somewhat to diminish the number of inspirations, but not generally to produce disease of the lung: the functions of the nerve of that side are also paralysed. If both nerves be divided, the respiratory movements are very much reduced, and the animal generally dies,—but often from disordered digestion. The lungs

always become congested, and as a consequence are filled with a frothy serum. The congestion arises from the insufficient aeration of the blood, owing to the diminished respiration.

The secretion of the gastric juice is supposed to be controlled by the nerve: according to others, this is not the case; but there is a paralysis of the muscular coat of the stomach, which impairs digestion. Bernard's recent experiments rather support the former view. The gastric secretion is, however, very much *influenced* by it. In the same way, the action of the heart is much influenced, but not controlled, by the par vagum. The superior laryngeal branch is an *excitor* or afferent nerve; the inferior laryngeal, a *motor* nerve. The two constitute the circle of excitor and motor nerves by which the aperture of the glottis is governed.

The functions of the *spinal accessory* are chiefly motor.

The *ninth* nerve or hypoglossal (*motor linguæ*) arises from a single root, and is distributed to the muscles of the tongue, and also to those muscles of the neck concerned in the movements of the larynx. Its function is almost exclusively *motor*.

The Sympathetic Nerve.—This nerve consists in a series of ganglia lying on each side of the vertebral column, communicating with the spinal nerves, and with large ganglia among the viscera. It has been named the *endo-nervous* system, to distinguish it from the cerebro-spinal, or *exo-nervous* system. The branches proceeding from the Sympathetic are not distributed to the muscles and skin, as are those of the cerebro-spinal system, but to the lungs and heart, and chiefly to the walls of the blood-vessels, which they accompany to their extreme ramifications.

Two sorts of fibres are found in the Sympathetic system,—the *white*, which are derived from the spinal nerves, and the *gray*, which belong exclusively to themselves. The trunks proceeding from the semilunar ganglia are nearly all composed of gray matter; and these are the true centres of the sympathetic system. Whatever degree of *motor* power the Sympathetic possesses,—as seen by the contractions of parts to which it is distributed on application of a stimulus,—is probably entirely due to its connexion with the cerebro-spinal system. The same is true of its sensory endow-

ments. Commonly, the parts supplied by the Sympathetic are not at all sensible, nor are the sympathetic trunks at all so. In certain diseased conditions of these organs, pain is manifested.

The *functions* of the Sympathetic are not certainly determined; they are believed to be the channel through which the emotions and passions affect the organic functions, particularly the circulation, as seen in syncope, blushing, and turning pale. The different secretions are also very much influenced by the mental emotions. We have no precise knowledge of the distinctive function of the gray fibres: possibly they may affect the *quality* of the secretions, whilst the white fibres may regulate the *quantity*, through the blood-vessels.

SECTION III.

OF SENSATION.

THE term Sensation signifies the *perception of an impression.* Properly speaking, there can be no sensation without a *mind* to be conscious of it; in the case of reflex action, there is an *impression* conveyed to the spinal marrow, causing motion, but without the consciousness of the individual, since it does not reach the brain, or *sensorium*, the seat of the perceptive faculties. Sensations are instinctively referred to the place where the impression is made, although the sensorium only takes cognizance of the impression made upon itself; thus we speak of a pain in any particular part of the body, the hand or foot, for example; whereas in reality the pain is *felt* in the brain. This is proved by two facts; if all nervous communication between the part and the brain be cut off, no impression, however great, can be felt; and if the *trunk* of the nerve be irritated in any part of its course, the pain which is felt is referred always to the part where the nerve is distributed. A familiar instance of this is afforded in the sensation produced by a blow on the ulnar nerve, causing a tingling sensation at the

extremities of the fingers; and the pain after an amputation, is referred, not to the stump, but to the fingers or toes that have been removed. We are ignorant of the mode in which an impression—a mere physical change—is made to act upon the sensorium, so as to excite consciousness in the *mind*.

The afferent nerves which connect the different parts of the body with the brain, are called *sensory;* whilst those which go to the spinal marrow, and which do not produce sensations, are named by Dr. M. Hall, *excitor*. Every afferent spinal nerve, then, is made up of both sensory and excitor fibres, and those parts of the body endowed with sensory fibres are said to be *sensible*.

Sensation is divided into General and Special. *General sensation* is that by which the body becomes sensible to surrounding objects,—causing a sense of contact, of resistance, of variation of temperature, of pain, &c. *Special sensation* is that by which we obtain impressions of a peculiar or special character, through the *special senses*, as vision, hearing, taste, &c.

General or common sensibility does not exist in all tissues in their natural state, as, for example, in the serous, mucous and cartilaginous. It appears greatly to depend upon the vascularity of the part; thus the epidermis, the hair, the nails, cartilages, ligaments, tendons, &c., have little or no sensibility, and little or no red blood circulating in them. On the contrary, the skin and other parts which are very sensitive, are also very vascular. Sometimes the non-vascular tissues become injected, as in inflammation, when they also become highly sensitive. Vascularity, however, is not invariably accompanied with a proportionate degree of sensibility, since this is not found, to any extent, in either muscles or glands, which are extremely vascular. An increased activity of the circulation of a part usually increases its sensibility; whilst a diminished activity lessens it: this is witnessed in the benumbing influence of *cold* upon the surface. The sensibility of the internal mucous membrane is less exalted by inflammation, than that of other parts; which is a wise provision, to obviate the pain that would arise from the constant movements of the viscera.

Sensations are termed *subjective* when they result from some

internal cause; *objective*, when produced by a material object. The subjective sensations often completely imitate the objective ones:—thus we have ringing in the ears, flashes of light, and occasionally, the senses of taste and smell, excited by internal causes. This, of itself, is a distinct proof that the impression produced upon the mind is due solely to the change communicated to the sensorium, and not to the change occurring at the *periphery* of the nerve. By *internal* sensations is understood, such as arise within the body; they are the result of some alteration in the function of the part not usually sensitive in health, and intended to direct the attention to the suffering organ.

Each of the organs of *special sensibility* requires its own peculiar stimulus to call it into action;—thus *light*,—the appropriate stimulus for the eye, has no effect upon the ear; *sound* produces no impression upon the eye; *odours*, none upon the tongue. Hence, the inference that no nerve of special sensation can perform the function of any other one. Neither is it believed that the nerves of common sensibility can act as those of special sense. Electricity is said to have the power, when transmitted along the nerves of special sense, of exciting the sensations peculiar to each. Mechanical irritation of these nerves will also produce an indistinct impression: thus, irritation of the optic nerve causes a flash of light; and irritation of the auditory nerve, a sensation of buzzing in the ear. The impressions upon the nerves of special sense, when too violent, produce pain; thus, a dazzling light, intense sounds, and powerful odours excite painful sensations. The final cause of this association of pain with such violent excitement is to prevent dangerous consequences,—as is seen in cases where there is a loss of this sensibility, in consequence of which, severe lesions arise; thus, violent inflammation of the air-passages has been produced by the inhalation of the vapour of ammonia, in syncope.

As a general rule, violent excitement of any sensation is unpleasant, even where the moderate excitement is very agreeable. But the question of the *degree* of excitement is relative, that is, a sensation may be extremely violent to one individual, which to

another more accustomed to it, would be not at all unpleasant. Thus, the sensations of heat and cold are governed by the previous condition of the parts affected; for example, by immersing one hand in hot water and the other in cold, and then placing them both in tepid water, the one will feel cool, while the other feels warm. The same thing is true of the other senses, as of vision, &c.; thus, a person going from a dark room into one moderately lighted, is painfully impressed with the glare; whilst one entering from a still brighter apartment will consider it dark and gloomy.

Although the frequent recurrence of a particular sensation, is apt to produce a diminished intensity, still, the complete *stoppage* of an accustomed sensation will produce as great an impression as its first commencement; this is witnessed in persons accustomed to constant noises, as a waterfall, or a forge-hammer, not being able to sleep when removed from them.

The acuteness of a particular sensation is very much influenced by *attention;* thus when the mind is entirely inactive, as in sound sleep, no sensation is produced by ordinary impressions; on the other hand, where the mind is strongly directed to them, even feeble impressions may cause acute sensations. We may thus, by a strong effort, so direct the mind as to receive only certain impressions having reference to a peculiar train of thoughts, and be unconscious of every thing else around us, as the ticking of a clock, music, conversation, &c. This power of abstraction may be voluntary or involuntary;—the latter is termed *absence of mind*, or *revery*.

We should distinguish between the sensations and the *ideas* which result from them, and which entirely depend upon a mental process. Thus, we behold an object with our eye; a picture of it is formed upon the retina which produces a certain impression upon the optic nerve; this is conveyed to the sensorium, where a corresponding sensation is excited, resulting in the formation of an *idea* of the object. The sensation and the idea are so closely connected, that we usually make no distinction between them. But sometimes we are liable to be deceived from this cause, as

when we look upon a well-executed picture on a plane surface, of an object in relief, the *idea* of the relief is at once excited, and will not be corrected until we touch the flattened surface. We find some of these ideas, or perceptions to be *intuitive*, that is, requiring no experience. This is particularly the case with the lower animals. It seems highly probable, also, that the idea of *erect vision* is intuitive to the human infant, since there is no reason why an inverted image upon the retina should give rise to the idea of an inverted object *in the mind*. Other perceptions are *acquired;* this is the case, for the most part, in man, whose power of acquiring perceptions, is far greater than in animals. Thus, the faculty of *measuring distances* seems intuitive in animals, but is acquired in man.

SECTION IV.

SPECIAL SENSATION.

Special sensibility is that by which a knowledge of the *special* properties of bodies is acquired. There are five special senses:—Touch, Taste, Smell, Hearing, and Vision.

THE SENSE OF TOUCH.—Touch may be defined to be that modification of the general sensibility having its seat specially in the skin. In man, nearly the whole surface is endowed with it, though some parts much more than others, especially the ends of the fingers and the lips. In animals, only certain portions of the surface are sensitive. The sense depends upon the minute distribution (or rather origin) of nerves in the sensory papillæ. These papillæ are minute elevations on the skin, enclosing loops of the sensory nerves surrounded by a vascular plexus. The sensibility of any part may be measured by estimating the number of papillæ within a given space. It is found to be greatest at the point of the middle finger, and least over the middle of the back, and middle of the arm or thigh. It is highly probable that upon the tips of the fingers, which are distinguished for the acuteness of

this sense, there is a true ganglionic expansion, as is known to exist in the retina. The special *centre* for the sense of touch is supposed to be the thalami optici.

The exercise of this sense requires *contact* with the object. The only exception is with respect to temperature, the mere proximity of the hot or cold body being sufficient. It is probable that the sense of temperature is somewhat different from that of ordinary touch: it may possibly be communicated through distinct sensory fibres. It has been discovered that no mechanical irritation of the nerves of common sensation will ever excite sensations of heat or cold; and instances are known in which the sense of temperature has been lost, while that of ordinary touch has remained, and *vice versâ.*

The only idea communicated to the mind by simple touch, is that of *resistance.* The notion of the *size* or *shape* of an object, or of the nature of its surface, can only be acquired by moving it over the sensory surface, or passing the latter over it. The *muscular sense* can only be called into action by movement. Hence, the human hand, which is capable of such a variety of movements, is so much superior, as an organ of touch, to that of any animal. The senses of touch and sight serve mutually to correct each other. The knowledge derived from the sense of touch, without the aid of the other senses, is very limited, as is seen in persons born both dumb and blind. It is chiefly through the sense of touch, aided by that of sight, that we derive the idea of the *materiality* of the external world.

There are certain modifications of this sense, which require a passing notice. *Tickling* is most readily excited in those parts which have the least tactile sensibility, as the arm-pits and soles of the feet. As regards the *temperature,* the left hand is said to be more sensitive than the right, though the converse is true with regard to common sensibility. *Extent of surface* is also concerned in this, since a weaker impression made on a large surface seems more powerful than a stronger impression made on a small surface: thus, if a single finger be put into water at 104°, and the whole of the other hand be immersed in water at 102°—the cooler

water will be thought the warmer. So again, the finger can, without pain, be held in a liquid sufficiently warm to produce a scalding sensation when the whole hand is immersed.

The sense of touch is capable of great improvement by exercise, as is seen in the case of the blind.

The Sense of Taste.—This sense appears to be a modification of that of touch. Like it, it requires actual contact of the body, and it is heightened by motion of the body over the gustative surface. All bodies do not excite this sense; but as a general rule, only such as are in solution, or are soluble. Such substances are named *sapid;* others, *insipid.* The cause of this difference is not understood. In animals, this sense is chiefly designed to direct them in search of food.

The *tongue* is the principal seat of the sense of taste; but other parts of the mouth are also somewhat concerned,—as the palate. The papillæ of the tongue are essentially the same as those of the skin, though some of them rather resemble a cluster of such papillæ,—containing a fasciculus of looped capillaries, together with one of nerves. Three varieties are usually described, the *calyciform* or *circumvallate*, situated at the base of the tongue, arranged in an angular form; the *fungiform*, on its sides and apex; and the *conical* or *filiform*, the most numerous, and situated in the central portion. No difference of function has been ascertained to exist between the different papillæ of the tongue, though the filiform have been supposed to be concerned rather in the sense of touch than of taste. When in contact with a sapid body, they often become turgid or erect, by a distension of their vessels, producing a roughness of the mucous membrane.

There is a difference of opinion as to which is the true nerve of taste. The tongue is supplied by the lingual branch of the fifth pair, which is distributed to the upper surface of its front, and to the papillæ near its tip; and also by the glosso-pharyngeal, which is distributed upon the back of the tongue, and mucous lining of the fauces, and also the edges, and inferior portion of the tip,—anastomosing with the former nerve. It is probable that both the sense of taste and touch are conveyed by means of the lingual

branch of the fifth pair from those parts of the tongue to which it is distributed; and that the glosso-pharyngeal performs the same office for the parts to which it goes; and it also seems to convey to the medulla oblongata, the impressions which produce nausea and vomiting. The latter nerve is also the chief channel through which the reflex act of swallowing is performed. The hypoglossal nerve is not believed to be at all connected with the sense of taste,—its functions, as before stated, being *motor*.

It is thought by some that all our knowledge of the *flavour* of a sapid body is derived through the organs of smell. It certainly is dependent upon that sense, as may be proved by firmly closing the nostrils, when the flavour of the substance in the mouth can scarcely be perceived. The same thing occurs when the Schneiderian membrane is inflamed, as in common cold in the head. A sapid body may excite a sense of irritation or *pungency*, as well as of flavour; such sensations are evidently of the same kind as those of touch; hence the sense may be regarded as a compound of those of smell and touch.

The sense of taste is more highly developed in animals than in man. It is capable of being rendered more acute by cultivation—as witnessed in *wine-tasters*, &c.

The Sense of Smell.—This sense conveys to the sensorium the impression of the odorous qualities of bodies suspended or dissolved in the air. It is seated in the olfactory bulbs, a true vesicular nervous expansion upon the ethmoid bone, though generally described as being located in the Schneiderian or pituitary membrane, upon which the olfactory branches are distributed. The arrangement of the ultimate fibres of this nerve has not been positively ascertained, though it is believed to be in loops: they cannot be traced to the inferior turbinated bones, consequently the whole of the nasal mucous membrane is not endowed with the faculty; it appears limited to that portion spread over the superior and part of the middle spongy bones. This portion has, from this circumstance, received the name of the *olfactory region*. The highest part of the nasal fossæ appears to be that in which

the sensibility appears to be most acute; hence, we *snuff in* the air when we want to distinguish delicate odours.

Odours depend on volatile emanations from substances. These emanations, however, must be extremely minute, since they often cannot be appreciated by weight, as in the case of a grain of musk not losing any apparent weight after exposure for many years. All volatile substances, however, are not odorous, as in the instance of water. A necessary condition for the sense of smell is that the membrane should be moist, and that its secretion should be in a healthy state. The temporary loss or impairment of smell from this cause is familiarly witnessed in what is termed "a cold in the head."

The acuteness of the sense of smell depends greatly on the extent of the membranous surface exposed to the action of odours; hence it is far greater in some animals than in men,—thus in the deer, the dog, &c. The habit of *attention* also, as in the other senses, heightens the sense of smell, as seen in the case of the blind, who are thus able to distinguish persons; also in the somnambulist, and in savage tribes.

In animals, this sense is of great importance in guiding them in search of food, in warning them of danger, &c., but in man it is of inferior consequence, and is not considered as an intellectual sense. Subjective phenomena are occasionally observed in this sense, arising, as in other cases, from some internal irritation. They have in some instances been traced to disease of the olfactory bulbs, and the anterior portion of the brain.

The influence of the nasal branch of the fifth pair is chiefly to control the secretions of the nose; thus, if it be cut, the secretion of mucus is arrested, and the sense of smell is nearly, if not quite lost, in consequence of the *dryness* of the membrane. It is also the nerve of common sensibility of the interior of the nose, receiving the impressions produced by acrid and irritating substances: in fact, it is the nerve by which such matters are *felt*, whilst the olfactory is the nerve by which *odorous* matters are *smelt*. The fifth nerve, moreover, is the channel by which the reflex

act of *sneezing* is excited; and this act will take place equally well after the olfactory is divided, provided the fifth remains entire.

The cavities which communicate with the nasal passages are not believed to be connected with the sense of smell.

THE SENSE OF HEARING.—The phenomena of the sense of hearing may very properly be divided into two distinct classes, viz.: those which are of a purely *physical* character, and those which are strictly connected with the faculties of perception. The former might have been described with great propriety under the head of "The Physical Actions of the Organism;" but they have been reserved till the present occasion in order to avoid any interruption in the subject.

The term *sound* is employed in two different significations: one to denote the specific impression made upon the auditory nerve—the *sense* of sound; the other to signify the undulations of elastic or sonorous bodies excited in their molecules, and propagated to the air, or to some other medium, as a solid or liquid. There are two sorts of sonorous vibrations; first, the undulations of inflexion, or by waves, where there is no onward movement of the molecules, but only an alternate elevation and depression, just as occurs in the undulations produced by dropping a pebble in still water; secondly, the undulations of expansion and condensation, as is witnessed in solids, where each molecule is alternately condensed and expanded.

Sound is produced by whatever excites the auditory nerve, as by mechanical or chemical irritation, by electricity, by certain medicines, as the narcotics and quinia, or by impressions originating within the brain as a consequence of disease of that organ. These last are the *subjective* sensations of sound, and they may amount to a species of hallucination, the individual fancying that he constantly hears peculiar sounds, or even voices.

Sound travels in the air with a velocity of 1125 feet in a second. In a dense atmosphere the velocity is increased, but in a rare one it is diminished; thus, a bell struck on a high mountain produces a very diminished sound. Different media also produce differences of sound; thus, hydrogen gas gives a very feeble sound,

while carbonic acid produces a louder one. Water is a better conductor of sound than air, the velocity in water being 4708 feet per second. Solid bodies are still better conductors than liquids. Hence two sounds may reach the ear from the same source—the first through some solid medium, as a wall, the second one through the air.

Sonorous vibrations, like luminous rays, may be interrupted by an opposing body. Two opposite vibrations of equal intensity will neutralize each other. Sonorous vibrations falling upon a surface undergo reflection like the rays of light; when reflected directly back, an *echo* is produced.

Certain conditions of Sound to be attended to.—Sound may be transmitted through all media, whether fluid, liquid, or solid; but not through a vacuum. The transmission is more rapid through solids than liquids; and more so through liquids than gases. The following conclusions have been estabished by experiment:—1st. Vibrations excited in solid bodies are transmitted to other solid bodies with greater intensity than to water, and to water with far greater intensity than to air. 2d. Sonorous vibrations excited in water are imparted with considerable intensity to solids; for though they do lose something of their intensity, the vibrations appear to be returned by the solids to the liquid, so that, in reality, the sound is louder near the solid body, than it would otherwise have been. 3d. Sonorous vibrations are communicated from air to water with much greater difficulty than from air to air; but their transmission is facilitated by the intervention of a membrane between them. 4th. Sonorous vibrations in solids are weakened in passing to air; so also are the vibrations of air, in being transmitted to solids.

The application of these principles to the physiology of hearing will be apparent as we proceed.

The ear is an acoustic instrument, constructed in exact accordance with the laws of acoustics. It contains the three conducting media of sound—air, solids, and a fluid. The *essential* part of the organ of hearing consists of an auditory nerve, so arranged as to receive sonorous vibrations. The perfection of hearing is very different in the various classes of animals. In the lowest order it

is limited merely to the appreciation of *noise;* and the apparatus is very simple, consisting only of a cavity or vestibule, hollowed out in the head, upon which the auditory nerve is expanded. The vestibule, then, may be considered as the fundamental portion of the organ.

It will be proper to examine briefly the different parts of the organ of hearing. The auditory apparatus, in its perfect form, consists of three parts, the *external, middle,* and *internal* ear.

The *external ear* is composed of elastic fibro-cartilage: it is divided into two portions,—the auricle or concha, and the meatus. In most animals the external ear is movable, by which means the sounds can be collected from any quarter, and concentrated towards a point. The very irregular surface of the concha enables it to receive sonorous undulations from every direction. Those which enter the meatus directly produce the most decided sound; hence we judge of the direction of sounds by turning the ear towards the source whence they proceed. The sounds which do not enter directly are reflected in such a way as finally to pass into the meatus. The concha also acts as a solid conductor of sounds.

The *meatus auditorius externus* is the canal leading to the tympanum. Its delicate lining membrane secretes the *cerumen* or ear-wax, which sometimes becomes so excessive as to prove a cause of deafness; at other times deafness is produced by an unnatural dryness of the meatus. Its solid walls will conduct the undulations from the concha inwards, whilst the air within it will also act both as a conductor of vibrations, and also by its resonance increase the intensity of these vibrations. This latter effect seems chiefly to be due to the length of the meatus, since the intensity of sounds is much increased by inserting a tube into the meatus, whereby it is artificially lengthened. The angularity of this canal no doubt causes the loss of many vibrations. The object of this angularity may be to prevent the ingress of foreign bodies. Some cases of dulness of hearing have appeared to be dependent upon an unusual angularity of the meatus.

The *middle ear* consists of the drum or cavity of the tympanum, with its membrane. The *membrana tympani* is the membrane stretched across the internal end of the meatus. It consists of three

layers. It receives the undulations both of the air and of the solid walls of the meatus, and transmits them undiminished to the chain of ossicles with which its internal surface is in contact. It is placed under the control of a muscle—the tensor tympani, which, through reflex action, regulates its state of tension; causing it to relax for the perception of grave sounds, and to become tense for acute ones. The action of this muscle adapts the membrane to the appreciation of various sounds, just as the iris is affected by light.

The perfection of hearing is to a great extent dependent upon the perfection of the membrana tympani. When its tension is very much increased, the hearing becomes less acute; this is shown by the experiment of a forcible expiration or inspiration, the mouth and nose being at the same time closed; according to Wollaston, it is only grave sounds which are thus affected. One probable use of this membrane is to protect the ear against very loud sounds by putting the membrane in such a state of tension as not readily to reciprocate them.

The *tympanum* or *drum of the ear* contains the chain of ossicles, consisting of the *malleus*—the handle of which is in immediate contact with the membrana tympani, the *incus*, the *os orbiculare* (considered by some a process of the incus), and the *stapes*. These little bones are so connected together as to form a bent lever, one extremity of which is attached to the inner surface of the membrana tympani, the other to the membrane of the foramen ovale. A small muscular apparatus is affixed to the chain, by which the degree of tension of the two membranes is controlled. By means of the chain of bones receiving the vibrations from the membrana tympani, an increase in the intensity of sound is secured, according to a law of acoustics, that a vibrating membrane transmits sounds with greater intensity when in contact with a solid body. Nevertheless, in some animals the chain of bones is entirely wanting, and in others it is reduced to a single bone. The tympanum has an outlet—the *Eustachian tube*—which opens into the pharynx behind the posterior nares. This canal is lined with a mucous membrane, covered with a ciliated epithelium. Several functions have been assigned to it, but its

probable office is to regulate the quantity of air necessary for the cavity of the tympanum, and also to afford an outlet for secreted mucus, by means of its vibrating ciliæ. Breschet supposes it is useful for conveying the sound of one's own voice to the ear. The cavity of the tympanum likewise communicates with the mastoid cells.

It will now be understood that the sonorous vibrations from the external ear are communicated across the tympanum to the internal ear, in three ways: 1st, by the air contained in the cavity of the tympanum; 2d, by the chain of bones to the membrane of the foramen ovale; 3d, by the parietes of the tympanum. The chorda tympani nerve is distributed to the inner surface of the membrana tympani. The tympanum has two other openings, each, however, closed by its own proper membrane—the *fenestra ovalis*, or *foramen ovale*, and the *fenestra rotunda*, or *foramen rotundum:* the former communicating with the vestibule, the latter with the cochlea of the internal ear.

The *internal ear*, or *labyrinth*, is the most important part of the auditory apparatus. It consists of several irregular cavities in the petrous portion of the temporal bone, in which the nerve of audition is distributed. These are the *vestibule, semicircular canals*, and *cochlea*. These are all lined with an extremely delicate membrane, and contain a limpid fluid, named the *liquor of Cotunnius*, or *perilymph of Breschet*. This fluid receives the sonorous vibrations, and communicates them directly to the filaments of the auditory nerve. The *membranous labyrinth* is a closed sac lining the vestibule and semicircular canals, but not extending into the cochlea. It contains a fluid named *endolymph*, similar to the perilymph which is on its exterior, between it and the walls of the bony labyrinth. The *vestibule* appears to be the most essential portion of the organ of hearing, as it often exists alone. It is a cavity communicating with all the other parts of the labyrinth. The *semicircular canals* are three in number; and as they lie in different planes, they have been supposed to aid in judging of the direction of sounds. They probably serve to collect the sonorous vibrations transmitted through the solid parts

of the cranium. The *cochlea* is the most anterior portion of the labyrinth, and is so named from its resemblance to a snail's shell. It is found only in the higher animals. It is a spiral canal, making two turns upon itself, and is divided, in its whole length, by a partition called *lamina spiralis,* so that two distinct tubes are thus formed, which are named the *scalæ of the cochlea.* These tubes run into each other, at the apex of the cochlea, but they have distinct openings at its base,—one into the vestibule, the other into the cavity of the tympanum, by the foramen rotundum. In the cochlea, the nervous expansions are spread out upon its floor,—the perilymph only intervening, so that vibrations from the solid portions of the head may be easily communicated to it, whilst the membranous labyrinth, being suspended in the perilymph, receives the undulations propagated through that fluid. Dugès supposed that the cochlea is connected with the *pitch* of sounds.

The labyrinth also contains certain small cretaceous masses, termed *otolithes,* which are especially large and hard in aquatic animals: they probably increase the intensity of sound by resonance, and by being in contact with the membrane of the labyrinth.

A single impulse to the auditory nerve is sufficient to excite *sound;* but it requires a succession of such impulses to constitute *tone.* The *pitch* of tones depends upon the number of vibrations in a given time; the high notes being produced by the most rapid vibrations, and the low notes by the slowest. For sound to be appreciated, the vibrations must be within a certain range. As determined by M. Savart, these must amount to 24,000 impulses, or 48,000 single or half vibrations, per second, to produce the *most acute* sound; and 14 to 18 half vibrations, or 7 to 9 impulses per second, for the production of the gravest sound. Despretz gives the limits of 32 single vibrations for the gravest, and 77,000 for the most acute sound. These extremes, however, are not reached by every ear, some not being capable of distinguishing a graver sound than one produced by 30 single vibrations in a second, nor a more acute one than that caused by 30,000 per second. Some ears are so constituted as to appreciate grave sounds only; while others can only distinguish acute sounds.

When the vibrations are perfectly regular and uniform, they constitute *tone;* when irregular, *noise* is the result. As the different musical notes, or tones, depend upon the different number of vibrations in a given time, each note has, consequently, its own number of vibrations, or *pitch*. These notes are distinguished by the first seven letters of the alphabet, A, B, C, D, E, F, G, and the whole combined constitute the *musical scale*, or *gamut*. The *loudness* of musical tones depends upon the force and extent of the vibrations communicated by the sounding body to the medium. The *timbre*, or quality of sound, is that peculiarity which distinguishes individual sounds, though of precisely the same note; for example, the same note when sounded by different kinds of instruments, has a different timbre; even similar instruments, if made from different materials, will give sounds of different timbre. Its cause is not perfectly understood.

Our ideas of the *direction* of sounds are acquired by habit: we may be assisted, also, by the relative intensity of the impressions upon the two ears. Some ascribe it to the semicircular canals. As regards the idea of *distance*, we are guided chiefly by the loudness or faintness of the sound; hence the ear may be deceived, as well as the eye, in making this estimate,—as seen by the imitation of a distant band of music approaching, by a *crescendo* of concealed instruments; and so also, in the ventriloquist.

An important office of the sense of hearing is to supply the sensations by which the voice is regulated. Hence, persons who are born deaf, are necessarily dumb also, even though there be no defect in their organs of voice.

THE SENSE OF VISION.—The sense of vision, like that of hearing, presents two distinct classes of phenomena, one—a physical—relating to the laws of optics, in which the eye as an optical instrument is concerned; the other, referring to the proper nervous phenomena.

By the sense of sight, we become acquainted with light, and also with certain external properties of bodies, such as form, colour, &c. Two different hypotheses have been entertained regarding the nature of light; the one originated by Newton—

that it consists of minute particles emanating from luminous bodies; the other, propounded by Descartes, Euler, Huygens, and others—that it is produced by undulations in an exceedingly elastic ether, which pervades all bodies, and that these undulations affect the retina, just as sonorous vibrations impress the auditory nerve. The *velocity* of light has been estimated at from 192,000, to 200,000 miles, in a second; a little over eight minutes being required for the light of the sun to reach the earth—a distance of over ninety six millions of miles.

Light travels in straight lines, through a uniform medium. When a ray of light passes from a rarer to a denser medium, it is bent or *refracted* towards a perpendicular;—when passing from a denser to a rarer medium, it is refracted *from* a perpendicular.

In consequence of this law of refraction, if parallel rays fall upon a double convex lens, they will be converged to a focus upon the other side. An object placed at a distance from such a lens, will form an inverted image upon the opposite side, on a screen placed at the focal distance. The farther the object is removed from the lens, the nearer will the picture be brought to it, and the smaller will it be. If the screen be not precisely in the focus of the lens, the picture will be indistinct; if too near the lens, the rays will not have met,—if too far, the rays will have crossed each other.

A ray of light falling upon a body may be disposed of in various ways: it may be *reflected*, *refracted* and *transmitted*, *polarized*, or *absorbed;* it may excite new undulations in the body, causing it to become *luminous;* it may meet another opposing wave, and become thereby *neutralized;* or it may produce *colours*. *Opaque* bodies absorb all the rays falling upon them; *transparent* bodies transmit them.

The rays of light proceeding from a luminous body must traverse different media before they can reach the eye; these media produce more or less deviation from the straight line, or *refraction* of the rays. White light on being refracted by a glass prism undergoes decomposition, as first demonstrated by Newton, forming the prismatic or solar spectrum. This is composed of the

following seven colours, denominated *primary colours* by Newton—*red, orange, yellow, green, blue, indigo,* and *violet,*—each one of which has a different refrangibility; the violet being the most refracted, the red the least. Since the time of Newton, other philosophers have considered white light as composed of three essential colours—*red, yellow,* and *blue.* The decomposition of light, explains the cause of the *colour* of different substances. When light falls upon a body, and all of its rays are reflected to the eye, it appears *white;* if all its rays are absorbed it appears *black;* if it reflects only the red ray, and absorbs all the rest, it is *red;* and so of all the other colours. The cause why one body reflects one ray, and absorbs others has been explained on the supposition of a different number of oscillations being excited in the ether for each colour,—the violet requiring a much greater number of vibrations in a second than the red. The estimated number of oscillations for the violet is 777 millions of millions in a second; for the red, 450 millions of millions, per second. Other invisible rays have been discovered beyond the limits of the spectrum; thus, just beyond the limit of the red ray, the thermometer indicates the existence of *calorific* rays; and beyond the violet extremity of the spectrum, *chemical action* has been observed to be most active. Hence, the inference that caloric, light, and chemical affinity are only modifications of a single great force of nature,—each being produced by different numbers of vibrations of an ether in a given time.

Light is the special excitor of the visual nervous apparatus, just as sound is the special excitor of the auditory nerve. The optic nerve, like the auditory, possesses no *common* sensibility, that is, it feels no pain on being cut or irritated; but any excitement, whether chemical or mechanical, produces the sensation of a *flash of light;* this is familiarly witnessed in a blow upon the eye; it is also produced by an electric current, or by cutting the nerve.

There are two phenomena of vision: the first is the simple perception of *light,* requiring merely a nervous expansion, as occurs in the lowest order of animals, just like their sense of hearing,

which consists only in the perception of noise. The second is the appreciation of distinct *forms* and *colours*, which requires a much higher development, since in perfect vision a distinct picture of the object is painted upon the retina, each point of the object being impressed upon it.

But, as in the other special senses, vision in reality is interior: it is an act of the *mind*, which alone can *perceive* the impression made upon the physical organ.

The apparatus of vision is constructed with the most perfect adaptation to all the laws of optics, and the properties of light. The human eye is an ellipsoid in shape, its long diameter being antero-posterior. It is composed of three membranes in superposition—the *sclerotic*, *choroid*, and *retina*, the latter being the one destined to receive the impression of light. Within these membranes, which may be compared to the case of a telescope, are four refracting bodies, situated one behind the other, and all intended to bring the rays of light to a proper focus, viz., the *cornea*, *aqueous humour*, *crystalline lens*, and *vitreous humour*.

The *sclerotic coat* is the outermost tissue of the eye; it gives shape and support to the organ, and constitutes the white of the eye. It is a dense fibrous membrane, and is liable to the different pathological conditions of fibrous tissue, as gout and rheumatism. It receives the insertion of the muscles that move the eyeball.

The *choroid coat* completely lines the sclerotic. It is a soft, thin, delicate membrane, composed of three laminæ,—an areolar layer, a vascular layer, and the innermost or epithelial layer, which consists of flattened nucleated cells, covered over with the *pigmentum nigrum.* Behind, it is perforated like the sclerotica, by the optic nerve; and within, it is lined by the retina. The choroid bears the same relation to the retina that the pia mater does to the brain, furnishing to it a large supply of blood. The object of the black pigment on its inner surface is to absorb the rays that have passed through the retina, and thus prevent any reflection, which would interfere with vision. It is deficient in *albinoes*, who consequently do not see distinctly in bright daylight.

The *retina* is the innermost coat; it lines the choroid, but is

separated from it by the *tunica Jacobi.* It is a soft, thin, pulpy, grayish membrane, and is usually, though improperly, described as being an expansion of the optic nerve. It must be examined immediately after death in order to study it, since it undergoes very rapid change. It consists of several distinct laminæ; the innermost one, or that in contact with the vitreous humour, being composed of numbers of very minute papillæ closely set together, and about the 1-8000th of an inch in diameter. This nervous arrangement is probably identical with the expanded nerve-matter on the tactile surface of the skin.

The *dioptrical* portions of the eye comprise the several refracting media—the cornea, aqueous humour, crystalline lens, and vitreous humour.

The *cornea* is the convex transparent anterior part of the eye. It is the segment of a smaller sphere than the rest of the ball, and is usually supposed to be composed of several distinct layers. The cornea transmits the rays of light which fall upon it at certain angles, and reflects from its polished surface those which strike it at other angles, causing an image, and giving brilliancy to its surface. The *aqueous humour* is a slightly viscid fluid, occupying the space between the cornea and the crystalline lens. This space is lined by a delicate hyaloid membrane, and is divided by the iris into two chambers—an *anterior* and a *posterior.* The specific gravity of the aqueous humour is about that of the cornea. Immediately behind the aqueous humour is the *crystalline lens,* the most important of all the refracting media. It is bi-convex, but more convex behind than before. It is contained in its own proper capsule; and between them is a slightly viscid secretion, called the *liquor Morgagni.* The lens is received into a depression on the anterior face of the vitreous humour, the proper membrane of the latter being reflected over it. It is composed of fibres interlacing with each other in such a manner as to increase its density from the circumference towards the centre,—an arrangement which contributes to render the eye perfectly achromatic. The *vitreous humour* occupies the whole space posterior to the crystalline. It is covered by a delicate hyaloid membrane, which is prolonged

internally, so as to divide it into cells; these communicate freely with each other. The composition of the aqueous and vitreous humours is nearly identical, being chiefly water holding in solution a little albumen, soda, and some lactates and muriates.

All the above refracting portions of the eye are liable to disease; the cornea to opacity; the lens also to opacity, constituting cataract; also to a separation of its fibres, causing indistinctness of vision; and the posterior humour to opacity, termed *glaucoma*, arising from a thickening of its membrane, and exhibiting a sea-green colour. The appearance termed *muscæ volitantes* is often due to globules of blood circulating through the vessels of this humour; in some cases, however, this appearance may be due to an abnormal state of the cornea, or to a hemorrhagic effusion into the lens.

There are two defects in ordinary convex lenses; the one, termed *spherical aberration*, results from the fact that *all* the rays passing through the lens do not converge at the same focal length; this causes rather an obscure image, unless the central portion of the lens only be employed. The other defect is called *chromatic aberration*, and results from the different refrangibility of the different colours of white light: this will cause a *coloured* image. In practice, these difficulties may be corrected by combining lenses of different densities and curvatures. This is admirably provided for in the eye, by the combinations of *humours* of different densities and curvatures.

The *iris* is a muscular diaphragm, or membrane, placed just anterior to the lens, having an opening in its centre called the *pupil*, through which alone the rays of light can enter the eye so as to reach the retina. The iris is the coloured part of the eye seen through the transparent cornea. It is composed of two sets of muscular fibres; the outermost, radiating, whose office is to dilate the pupil; and the innermost, circular, for contracting it. In man, the pupil is circular; but its shape varies in different animals. Its vessels and nerves are branches of the ciliary. The contraction of the iris regulates the amount of light which enters the eye; the pupil always becoming smaller in a bright light, and

expanding in the dark. It is governed by reflex action,—the optic nerve being the *afferent*, and the third pair the *efferent*. The iris also, most probably, contributes to correct the spherical aberration of the lens, by allowing the rays of light to fall only upon its central portion.

The luminous rays, after undergoing refraction through the above media, are conveyed to a focus a little anterior to the centre of the vitreous humour; this point is named the *luminous focus;* after passing this, the rays diverge, and form the *visual focus* upon the retina. The visual focus falls exactly upon the *yellow spot of Sömmering*, which is directly in the axis of the eye, and about 1-6th of an inch outside of the entrance of the optic nerve. At the last-named spot, vision is entirely absent. The perfection of the image here formed will depend chiefly upon the proper shape of the lens. If this is too convex, the image will be formed anterior to the retina, and will constitute *myopia*, or *short-sightedness;* if not sufficiently convex, the image will be formed behind the retina, constituting *presbyopia*, or *far-sightedness*. The remedy for the first defect is double concave glasses, whilst double convex glasses will correct the second. The presbyopic condition is well marked after the operation for cataract, when the removal of the lens greatly diminishes the refractive power of the eye.

The accessory portions of the organ of vision have also their appropriate offices, which are chiefly protective and motor,—the latter being performed by six muscles. The *lachrymal gland* secretes the *tears*, which are designed to constantly moisten the surface of the eye: they are spread over its surface by the frequent involuntary winking of the organ. In some low forms of fever this movement of the eye ceases to occur, and dryness of the cornea, and consequent opacity ensue.

There are certain phenomena connected with vision, which require to be noticed. One of these is the cause of objects appearing erect, when it is well ascertained that their image is painted upon the retina reversed. Various explanations have been offered, but the most reasonable is that which refers it to the *mental act*,

which alone takes cognizance of the visual impression, and refers it to the object producing it.

The cause of single vision when both eyes are used seems to depend very much on habit. The only condition necessary is that the images should be formed upon the parts of the two retinæ which are accustomed to act together,—depending on the chiasm of the optic nerves; thus, if while looking steadily at an object, we press one eyeball so as to change the position of the image, we see two representations of the object. The same thing occurs in strabismus, and in various disorders of the nervous system; but if this morbid condition becomes permanent, the vision ceases to be double, the eyes becoming accustomed to act together in their new relation. The peculiar arrangement of the nervous apparatus is also doubtless concerned in the phemomenon of single vision. In fishes, whose eyes are placed laterally in the head, the optic nerves are not connected by a chiasma, as in the higher animals, but simply cross each other. According to Mayo, the optic nerves consist of three tracts, the innermost of which is purely commissural, connecting together the two retinæ anteriorly, and the optic ganglia posteriorly; the outer tract does not decussate, but supplies the outer portion of the retina of the same side; while the middle tract alone decussates, and supplies the inner portion of the opposite eyeball. Hence, according to this view, the right optic nerve supplies the right side of each eye, and the left nerve, the left. The experiments of Magendie, however, would seem to prove a complete decussation of the optic nerves. Admitting the first of these views, we may easily conceive that corresponding impressions made upon the two eyes will be transmitted to corresponding points in the tubercula quadrigemina or optic ganglia, and will excite but a single sensation; whereas, if they be made upon parts not corresponding, two distinct perceptions will take place, and two objects will be seen.

The adaptation of the eye to distances is a point in the physiology of vision, that has given rise to numerous speculations. One theory supposes that the antero-posterior diameter of the eye is altered so as to adjust the refracting media to their proper dis-

tances, or that the lens and cornea are altered in their convexity; in either case there would be a change in the focal distance in the eye. Sir David Brewster and other recent writers suppose that this power of adjustment depends upon the contraction and dilatation of the pupil; as when we look at a near object the pupil always contracts, so as to exclude the most divergent rays; and when a distant object is viewed, it dilates. Another theory refers it to a change in the position of the lens by muscular agency. It is the opinion of Dr. C. Wallace, that the ciliary muscle advances the lens by compressing the veins, thereby producing an erection or lengthening of the ciliary processes. It is an interesting fact that the adjusting power of the eye is greatly impaired, or even lost, by extraction of the lens, or by paralysing the ciliary and iridial muscles by belladonna. A very minute alteration, in the position of the lens would be sufficient to account for all the range of vision required. There is still another hypothesis—that of Sturm—which refers the cause of the adaptation of the eye to distances to some peculiarity in the refracting media.

The perception of the impressions made upon the retina is purely a *mental* process; and this may be either intuitive or acquired;—the latter is most common in man; the former, in animals. The idea of *solid* forms is entirely acquired through the aid of *touch*,—as is proved in the case of a person affected with congenital cataract, who had afterwards been restored to sight, regarding every object as a flat surface.

The idea of the *distance* of objects arises also from the association of the tactile with the visual sensations. In regard to near objects, the degree of the *convergence* of the eyes may assist; in regard to very distant objects, we judge of their distance by the apparent size, if their real size is known to us; but if we are ignorant of this, then we judge by the greater or less distinctness of the object; and hence, we are liable to be deceived. The estimate of the size of an object is closely connected with that of its distance, and is dependent, chiefly, upon the degree of convergence of the axes of the two eyes: this is particularly the case for objects very near to us; in more distant objects we may be easily deceived. The association between the tactile and visual

impressions enables us to judge of *smoothness* (a quality essentially the object of touch), by vision merely; also of *polish*, which, though essentially the object of sight, is easily recognised by the touch.

The *contraction* of the pupil under the stimulus of light is effected by the muscular contraction of the iris. It is purely a *reflex* act,—the impression being conveyed to the nervous centres by the optic nerve, and the motor power transmitted to the iris by the third pair. It is entirely independent both of the will and consciousness of the individual. The *dilatation* of the pupil is probably due to the elasticity of the iris. The design of the contraction of the pupil is to exclude any injurious amount of light from the interior of the eye. There is a certain contraction of the pupil which takes place without any change in the amount of light; it occurs when the two eyes are made strongly to converge upon a near object; and the purpose seems to be to prevent the rays from entering at such a wide angle as would form an indistinct image.

There is a tendency in the luminous impressions made upon the eye, like those made upon the ear, to remain for a short interval. This duration of the visual impression is familiarly seen by causing a luminous body to whirl around: it is found to vary from one fourth to one tenth of a second; it also explains the optical delusion in the toy known as the *thaumatrope*. The same explanation will also account for the phenomena of *accidental colours*. When the eye has been steadily fixed for a length of time, upon one particular colour, the retina becomes fatigued, and loses its impressibility to that colour; if now the eye be turned to a white ground, a spot having a different colour will be observed; this will be made up of all the colours of the solar spectrum, *minus* the colour first seen; and the resulting one colour is termed the *accidental* or *complementary colour*.

The impressions of *colour* are produced by the differently coloured rays which objects reflect or transmit to the eye. Some persons are not able to distinguish colours, although in other respects their vision is perfect.

CHAPTER VI.

REPRODUCTION OR GENERATION.

The several functions and organs which have been described in the previous chapters have reference to the individual being. Those which are concerned in the production of a new being, or the propagation of the species, will next claim our attention.

In many essential points the function of reproduction is similar to that of nutrition; both are concerned in the formation of new parts. There is this difference, however, that in the former the newly-formed parts are generally, if not universally, the products of two distinct germs, and are destined to be cast off from the parent structure and to become a new being; in the latter, they are simply a repetition of the original forms, and are designed to continue as a part of the original whole. The resemblance between the two is seen in the simplest cryptogamia, as the *yeast-fungus*, where every single cell is a new being, and where the process of nutrition is, at the same time, that of reproduction. The same thing is witnessed in the lowest animals, as the polypi.

It will be presently shown, however, that true generation, even in the lowest vegetables, requires the union of the contents of two distinct cells, by which the *germ* of the new being is evolved. It will also be seen that the apparent exceptions to this rule, in the case of the simpler plants and animals, where multiplication is the result of mere segmentation of the original cell, can be satisfactorily explained by referring them to a process of growth or development, rather than to one of generation. In the higher vegetables and animals, there is no difficulty in recognising the distinction between the *ovo-cell* and the *germ-cell*. In the vegetable, these two sets of organs are very often united in one in-

dividual,—the same flower furnishing the pollen and the ovule. In some animals, as the mollusca, the same union of organs occurs. The two sets of organs may be present in each individual, and yet coition be necessary for mutual impregnation. Finally, the sexes may be entirely distinct,—one individual possessing only the *male* or germ-producing organs, the other, the *female* or germ-nourishing apparatus.

In order to understand correctly the function of Reproduction, it will be requisite to notice the history and development of the *germ,* since from it directly the new being is developed. On the germ is impressed, so to speak, the whole idea of the future being; on it is sketched out the plan, which is subsequently to be gradually unfolded, until at length the perfect organism is completed in all its details. It is through the germ that successive generations of the various species of living beings succeed each other, each one preserving the characteristic traits, which identified its predecessor. At its commencement, it is but a microscopic point; it is the seat of a wonderful force, peculiar to itself, called the *germ-force;* this has previously been noticed as one of the indispensable conditions of vitality; if it be absent in the organizing process, although there may be present all the other conditions, as a healthy plasma, and a normal temperature, no *form* can be evolved, but there will only result the ordinary chemical affinities, terminating in decomposition. This is well illustrated in the egg, which has been laid before impregnation by the male; if this be submitted to the temperature proper for incubation, it only undergoes putrefaction: wanting merely the germ-force, its otherwise healthy material is incapable of taking an organization. To the germ then, belongs the property of imparting specific forms to the whole being, and also to the various organs. Its essential character is that it is capable of being developed into a complete being.

The germ is the primordial of all the organic forms; it is always the product of two distinct materials derived from two different cells—the *ovo-cell* and the *germ-cell;* and these may be produced by the same individual, or, as is most common, by different individuals. The ovo-cell is the product of a special organ named

the *ovary;* this may be regarded as a species of gland, which prepares the ovo-cells or ovules by a sort of secreting process. The ovary is found to contain the ovules in every stage of development, from the minutest granule, to those in the farthest state of advancement, in which the germinal spot can be discerned. As one of these ovules is gradually perfected, it advances from the centre of the ovary towards its periphery; here the walls of the ovary and ovisac are observed to become thinner, and finally to open, so as to permit the ovule to pass out into the oviduct or Fallopian tube, and through this, into the uterus. Now, all the above processes may take place without the admixture of the germ-cell, and of course without any farther development into a germ. Indeed, there is good reason to believe that, as in the lower animals, there is a constant throwing off, in this manner, from the human female, of blighted ova, from the absence of the male impregnation. To constitute the ovule, then, into a true germ, it must mingle with the product of the other cell—the *germ-cell,* as already mentioned.

The contents of this germ-cell vary; in some of the lowest animals it contains only a single granule; but usually, it consists of a number of filamentous bodies, termed *spermatozoa,* which are generally arranged in bundles, and are probably the result of secretion, since they are contained in a cell, and are observed in progressive states of development, only arriving at maturity when the animal is capable of procreation. The nature of these spermatozoa is not yet fully determined. At one time they were supposed to be animalcules, because they have the power of spontaneous motion; but it is much more probable that they are merely filaments, endowed with a property of motion analogous to that observed in the pollen-tubes of plants. Their existence constitutes the essential character of the male cell. Absolute contact of the two cells is indispensable to insure a successful impregnation, or the production of the germ. Experiments have shown that the spermatozoa penetrate as far as the superior third of the Fallopian tubes, and according to Barry, even to the ovary itself.

From the above brief description, which applies especially to the highest animals, it is obvious that the germ, which is always

the result of two distinct cells, must be endowed with the peculiarities of each; for the ovo-cell, being originally part of the material of the ovary, must be affected by all its modifications, through disease, &c., and likewise by every cause influencing the general health of the mother, since the ovary must participate, in the general condition of the system. In the same manner, the germ-cell partakes of all the peculiarities of the male parent, being originally a part of its material; and hence it results that the new being inherits the different tendencies of each of its parents, both physical and mental, and often moral. In this manner, also, we can readily understand the transmission of *disease* through successive generations.

The influence of the male fecundating principle is not limited to a single impregnation, but it appears to affect, to a greater or less degree, successive conceptions, even when these are brought about by the agency of another male. Instances of this are familiar to the breeders of dogs; but the best example of the kind is afforded in the case of a mare, which was covered by a male quagga, in India; after producing a hybrid, she was subsequently put to the horse, but twice, successively, her foals bore distinctive marks of the quagga,—evidently showing that the influence of the first impregnation had been transmitted to the subsequent germs.

There are three different methods by which the germ is produced by the union of the reproductive cells: 1st. By *conjugation*, or by cells placed in apposition, as seen in the simplest algæ, or in the lowest cellular animals; these two cells burst, and mingle together their contents. In vegetables they are termed *sporangia;* they are frequently so minute as to float about in the atmosphere, incapable of detection, until they find their peculiar soil or nidus, in which they soon develope themselves in the form of *moulds.* 2d. By *moving filaments,* endowed with great activity of motion. These exhibit certain evidences of organization. They are produced in the testes of animals, and in certain parts of plants. In the higher animals they receive the name of *spermatozoa,* or *spermatozoids.* The motion of these filamentous bodies appears to constitute an important part of their function,

since in every successful impregnation they find their way to the ovule. In the higher algæ and cryptogamia the process is very similar,—filaments being thrown out from one, and finding their way to the other, and then uniting, so as to constitute a germ. 3d. The *method of flowering plants.* In these, the anther contains the pollen-cell, which is equivalent to the germ-cell of animals; the female organ consists of the pistil, surmounted by the style; this is moistened by a secreted fluid, and receives the pollen-cell, which bursting, discharges the pollen-tube; the latter, which bears some resemblance to a spermatozoid, passes down the hollow pistil and reaches the ovary, and according to Schleiden, penetrates the ovisac so as to come into actual contact with the ovule; others deny that it actually enters through the ovisac, but believe that its contents first become liquid, and then pass in by endosmose.

Numerous theories have been advanced in relation to the respective parts which each sex performs in the formation of the germ. The most important are the following: Leuenhoek, followed by Boerhaave, Keill, Cheyne, and others, believed that the male alone contributed the true germ, the female affording only the nutritive material or embryotrope, for its future development. MM. Prevost and Dumas believe that the spermatozoids penetrate into the interior of the ovum, and there constitute the rudiments of the nervous system of the new being,—the organs of organic life being furnished by the female. This, however, is disproved by the microscope. St. Vincent supposed that the spermatozoa were only carriers of the sperm to the ovary; but this notion is disproved by the fact that in frogs and fishes impregnation takes place after the extrusion of the ova from the female.

The positive facts now known in relation to the subject are the following: the spermatozoids must always be present in the spermatic fluid to insure impregnation; this is proved by destroying these bodies either by electricity, or by filtering the semen of frogs,—the liquid which passes through the filter produces no effect upon the ova. Again, experiment proves that these bodies do actually pass into the uterus and Fallopian tubes, and possibly into the ovary. In the Fallopian tubes the ovum becomes sur-

rounded by an albuminous covering, which subsequently constitutes the white. In birds, and cartilaginous fishes, and non-scaly reptiles, the *cicatricula* is the true ovum, and corresponds with the *vitellus* of the mammalian ova. The spermatozoa have been seen to penetrate as far as the vitelline membrane; here, *it is probable* that they become liquefied, and that they are thus enabled to penetrate into the interior of the vitellus, by endosmose.

After fecundation, the germ acquires the power of an independent existence. A peculiar series of changes immediately commences in it; in the point previously occupied by the germinal spot, a new body appears, in the shape of two cells, which seems to influence the whole contents of the ovum. These cells speedily multiply by division or segmentation, each one becoming two, and this process of doubling continuing until the whole is converted into countless granular bodies,—*each one of which* must necessarily be endowed with all the properties of both the male and female organism; consequently, every part of the organism of the new being must partake of this influence.

There are some apparent exceptions to the above law of development of the germ; but when properly examined, these will not be found to be real; they are the following: 1st. *Propagation by division*, or *scission*. This is witnessed in some of the lowest animals; but even here it has been found that the central germ has *first* divided, so as to contribute a portion to each of the segments. 2d. *By budding* or *gemmation*.—This process occurs in the hydra, or fresh-water polype. A swelling is observed on the side of the animal, which increases like a sprout or bud, and is finally prolonged into a new animal, which, however, communicates with the cavity of the parent. After a time, this offset separates and becomes an independent being. This process continues till towards the close of the animal's life, when a new cell forms at the side containing a germ; more frequently two cells are formed, each containing a new germ—one male and the other female; the animal then liquefies around the germs. 3d. By *alternate generation*, or *parthenogenesis*.—This is seen in the *aphis*, where from a single egg are developed in rapid succession numerous progenies

of beings, all females, and viviparous. At the end of summer a male is formed; copulation then takes place, the result of which is an egg; this lies dormant till the following spring, when it hatches to produce the similar *virgin* progeny as before. Mr. Owen explains this mode of reproduction, by supposing that there is a superabundance of the germinal granules in the original germ above what is required for a single being, and that in consequence a succession of *buddings* takes place in the interior of the animal, just as occurs on the exterior of the hydra. 4th. *Propagation by successive generations.*—This is exemplified in the common polypi; but here the exception is also only apparent, for the successive generations are really only the development of the various phases of the *same* animal, or rather of its embryonic existence, just as in insect-life, the changes from the larva progressively to the pupa and perfect imago are but successive steps of embryonic development.

Just in proportion to the complexity of the animal is the completeness of the connexion between the embryo and the mother; in the simplest and lowest animals this connexion is slight, and soon severed; in the highest, it continues for a long space of time, until the complex development is completed.

Action of the Male.—The reproductive action of the male consists in the formation and liberation of the reproductive germs contained in the seminal fluid. These are prepared within the peculiar cells of the tubuli semeniferi of the testicle, and are named *spermatozoa.* They exist in no other secretion, and in the testis only when the animal is capable of procreation. They may consequently be considered as an instance of the highest power of cell-action, and they afford an illustration of what Schwann calls the *metabolic* force of cells. Their complete development does not appear to occur until the semen has reached, or has for some time lain in, the vesiculæ seminales. In their earlier condition they do not exhibit their characteristic appearance, but are in a rudimentary state. The spermatic cells of man before puberty resemble those of certain animals in the intervals of the rutting season, in being very small and shrivelled. In

their process of development, they lose their granular character, and swell up, and exhibit within them a variable number of secondary cells. Within each one of these last is produced a single thread-like body, which at first is coiled up within its envelope; but very soon this bursts and allows it to escape. Sometimes this occurs before the secondary cells have escaped from the parent-cell, so that the latter appears filled with a bundle of spermatozoa.

The human spermatozoon consists of a little oval, flattened body, from the 1-600th to 1-800th of a line in length, from which proceeds a long tapering tail, about the 1-50th of a line in length,—the whole transparent. It is distinguished by its powers of spontaneous movement, which has caused it to be considered as a proper animalcule; but it is now believed to be analogous to the pollen of plants, which often exhibits the same tendency to rapid movement when separated from the parent structure. The movement is principally performed by undulations of the tail, and may continue for many hours after emission of the fluid; and it is not checked by their admixture with the urine, &c. They can be detected by the aid of the microscope, in the urine, in cases of nocturnal emission. They are developed within the seminal cells, and arranged in bundles.

The power of procreation in the human male, is not generally found before the age of fourteen to sixteen years. This period is called *puberty*. Certain characteristic changes then occur—as development of the sexual organs, growth of hair on the chin and pubes, enlargement of the larynx producing hoarseness of voice, general enlargement of the frame, and the awakening of new feelings and desires. The procreative power may last, if not abused, in vigorous persons, to the age of sixty to seventy years, or even longer. The secretion of semen is very much under the influence of the nervous system. Its *excessive* formation appears to be a tax upon both the mental and bodily powers; it is a law both of vegetables and animals, that the development of the individual and the reproduction of the species are in an inverse ratio to one another.

The emission of semen is purely a *reflex* act,—being entirely independent of the will. Under the stimulus of the venereal excitement, an impression is produced upon the spinal cord, which causes a reflex contraction of the muscles surrounding the vesiculæ seminales; these receptacles discharge their contents into the urethra, and from this they are expelled by the compressor muscles. *Sensation* is not absolutely essential to the act, for the impression conveyed to the spinal cord may excite the contraction of the ejaculator muscles, like other reflex actions, without producing sensation.

Action of the Female.—The office of the female is to receive the germ prepared by the male, and to supply it with nourishment for its future development. The process by which this is effected is essentially the same as in plants: peculiar bodies, termed *ova*, are produced in certain parts of the female structure; these contain a store of nutriment. The reproductive germ reaches the ova, and begins to grow at the expense of the materials which they yield. This may be all that the embryo requires, save a warm temperature, to develope itself into a perfect being—as is the case in birds and reptiles, in which the development of the embryo takes place separate from the mother; or it issues from the egg in a form different from what it is permanently to assume, but still capable of supporting itself;—this is the condition of most of the invertebrata; or a new connexion is formed between the embryo and the mother, by which the latter continues to supply the former with nutriment from its own blood, as in the mammalia and man. The changes of insects from the larva up to the perfect form are to be regarded only as an embryotic development.

The condition of the *ova* varies in different animals: in the lowest, they are scattered throughout the body, just as are the seminal cells: in others, they are contained in tubes; but in the bird, reptile and mammal, and in most fishes, they are in masses of parenchyma, copiously supplied with blood-vessels, and having dispersed through their substance certain peculiar cells termed *ovisacs*, within which the ova are developed. In order that the

ova may be set free, not only must the ovisac itself burst, like parent-cells in general, but the peculiar tissue and the envelope of the ovarium must give way. When the ovum has thus escaped into the cavity of the abdomen, it may either remain there, to be shortly discharged by simple openings, in the walls,—as in the case with certain fishes, or it may at once be received into the expanded extremities of tubes called *oviducts,* to convey it out of the body. In mammalia, the oviducts are named *Fallopian tubes;* but these unite and enlarge to form a *uterus,* in which the embryo is retained for further development. The uterus is peculiar to mammalia; but in many of the other animals the embryo is retained within the oviduct till it has been sufficiently developed to be born alive.

The structure of the *ovule* or unfertilized egg, is essentially the same in all animals. Neither the albumen which forms the white, nor the shell with its membrane, exist in the ovum until after it has left the ovary; and in some cases, as the lower invertebrata, they are not present at all. The *true* ovule consists of the yelk-bag and its contents—the yelk. The yelk or yolk is composed chiefly of albumen and oil-globules; and it is this substance, which, like the starchy and oily matter laid up in the seed of plants, is destined to nourish the embryo till it is able to support itself, or, as in the case of mammals, form a new connexion with the parent. Floating in the yelk is a peculiar cell, termed the *germinal vesicle;* and upon its wall, a distinct nucleus, called the *germinal spot.* In the mammalia the yelk is much smaller than in birds, because it is intended to afford nutriment only in the earliest stage of the embryo.

The capsule or investment of the ovum is termed the *Graafian follicle,* the inner layer of which is the proper ovisac. The ovisac and ovule are not in immediate contact: between them we have a layer of cells surrounding the ovule, termed *tunica granulosa;* another layer lines the ovisac, and is called *membrana granulosa.* These two membranous expansions are connected together by four band-like extensions, named *retinacula:* they appear to suspend the ovum in its place.

Ova are seen in the ovarium of the fœtal animal; and during the period of childhood there is a continual rupture of ovisacs, and a discharge of ova, but these are not sufficiently developed to be fit for impregnation. Their evolution takes place much more rapidly and completely about the period of *puberty*, at which time the stroma of the ovarium is crowded with ovisacs. This same increased development of ova is seen also during the period of *heat* in animals, whose powers of conception are periodic. The period of puberty in the human female is usually between the thirteenth and sixteenth year. It is generally supposed to occur earlier in warm climates than in cold, and in towns than in the country. The period is also hastened by luxurious habits, an inert life, and sensual indulgence. The changes which occur in woman at this time are chiefly connected with the reproductive organs: as development of the mammæ, increased size of the pelvis, but above all, the appearance of the catamenia.

The *menstrual* or *catamenial flow* is always an indication of the aptitude for procreation; but, as it is often delayed, its absence is no criterion of an inability for this function. The interval between the successive appearances of the flux, is about four weeks: the *duration* of the flow, from three to six days; but the return is apt to be more frequent, and the duration longer, in females of luxurious habits and relaxed frame. The first appearance is usually accompanied by considerable disturbance of the system. It is believed to be a true secretion effusion from the lining membrane of the uterus, and is regarded as true blood, having its characters somewhat altered by mixing with the vaginal mucus, which prevents its coagulability. The appearance of clots is an indication of *abnormal* menstruation. The catamenia are not entirely confined to the human female; a similar secretion is observed in most of the mammalia during *heat*. The chief peculiarity in woman is its *monthly* return. Recent observations confirm the fact, that the condition of the female generative system, during menstruation, is similar to that of animals during heat, that is, there is then a greater tendency to conception; also, that at this period there is usually a discharge of ova, by the rupture

of the ovisacs, more frequently than at other times; but still, that menstruation may occur without any such rupture. The duration of the procreative power of the female, as marked by the catamenia, is usually till about the forty-fifth year; though occasionally prolonged ten or fifteen years longer. Generally, there is no menstrual flow during pregnancy or lactation, though this is not invariably the case, particularly as regards lactation.

The function of the female during coitus is entirely passive. The secretion and discharge which occur during excitement arise from the *glands of Duverney*, small, rounded, elevated bodies, situated at the entrance of the vagina, on either side;—they are analogous to Cowper's glands in the male, and discharge upon the inner surface of the nymphæ. All that is necessary to insure impregnation, is the introduction of a small quantity of the spermatic fluid just within the vagina. It is uncertain how the spermatozoa make their way to the ovum, but it is believed to be by their own inherent power of motion.

The human ovum is extremely small, measuring, according to Bischoff, from 1-240th to 1-120th of an inch. Its external investment is a transparent membrane about 1-2500th of an inch in thickness, which under the microscope appears as a bright ring, bounded both externally and internally by a dark outline; it is named the *Zona pellucida* or *vitelline membrane*, and corresponds with the chorion of the impregnated ovum.

Changes in the Ovule before Fecundation.—When the ovule is nearly at maturity, it begins to move from the centre of the ovisac, where it had been suspended by the retinacula, towards its periphery, and always to that side of it which is nearest the surface of the ovary. In the mean time, the portion of the ovisac in immediate contact with the ovum thins away, and the outer portion, or the Graafian follicle,—especially that part most deeply imbedded in the ovary, becomes thicker, by a deposit of fibrinous matter between this layer and the proper ovisac. This produces pressure of the ovum against the thinnest part of the vesicle, which ruptures, and allows it to escape into the entrance of the Fallopian tube.

The fibrinous matter just alluded to, together, as it would seem,

with the remains of the ruptured ovisac, becomes organized, and forms the *corpus luteum.* This is the history of the escape of an ovule from the ovarium, whether impregnated or unimpregnated; but the *corpus luteum* of the pregnant state is much larger and more highly organized than that of the unimpregnated condition. After delivery, its size rapidly diminishes, so as very soon only to leave a cicatrix.

Changes in the Interior of the Ovum.—While the ovum is moving towards the periphery of the ovisac, the yelk becomes filled with cells, which, after passing through successive generations, finally disappear, leaving the fluid apparently in the same condition as before. This process of cell-development in the yelk continues for some time after fecundation; its object seems to be, to prepare the matters of the yelk for their future functions in the nutrition of the embryo. At the same time, the *germinal vesicle* is moving from the centre of the yelk to its periphery, and always to that side of it which is nearest to the ovary; and the *germinal spot* is always on that side of the vesicle which is nearest to the yelk-bag;—thus, we find the germinal spot to be very near the surface of the ovary. A successive development of cells takes place in the germinal vesicle, commencing upon the edge of the germinal spot, and sprouting forth towards the centre. These cells enlarge, and another ring of them is developed within; and so on, successive annuli of cells, one within the other, until the whole germinal vesicle is filled with minute cells, except the centre of the germinal spot, which remains pellucid. According to Mr. Newport and others, the germinal vesicle then bursts, and diffuses these minute cells through the yelk; and this disappearance of the germinal vesicle, with its germinal spot, may occur before fecundation,—sometimes before the ovum leaves the ovary, and always prior to the segmentation of the yelk.

By the above changes, we see how the germinal vesicle is brought very near the surface of the ovary. It is still covered, however, by the peritoneal coat of the ovary, by the Graafian follicle, by the ovisac, and the yelk-bag, which in mammalia is termed the *zona pellucida.* The three former of these, as we have

noticed, gradually become thin, and rupture, allowing the ovule to escape; and according to some authorities, about the same time, the zona pellucida divides, so as to form a chink just above the pellucid centre of the germinal spot; and it is through this fissure that the spermatozoa reach the vesicle, so as to fertilize it.

Of the precise *influence* communicated by the spermatozoon upon the ovum nothing definite is known: absolute *contact* between them appears to be essential. According to Mr. Newport's recent investigations, when this contact occurs, the spermatozoa undergo solution, and become intimately blended with the contents of the ovule, very much after the manner of the "conjugation" of the lower order of plants. It is not quite certain whether the process of fecundation takes place, in mammalia, before the ovule has burst the ovisac, or while it is passing along the oviduct. It most probably varies according to the point at which the ovum may happen to come in contact with the seminal fluid.

Changes occurring after Fecundation.—The first change noticed in the mammalian ovum after fecundation, and corresponding to its passage through the second half of the Fallopian tube, is the cleavage or segmentation of the yelk. According to Bischoff, whose observations were made upon rabbits and bitches, the yelk, which was previously compact and uniform, resolves itself into two, then into four, then into eight segments, and, so on, by a process of doubling, until the whole cavity of the zona pellucida or vitelline sac becomes filled up with a mass of spheroidal cells, giving to it the appearance of a mulberry, whence it received the name of *mulberry mass.* Each one of these segments contains a transparent vesicle which may be surmised to be composed of the elements of the original germ. Bischoff does not consider either the segments or their contained vesicles, at the earlier stage of this change, to be true cells; but soon after the ovum has reached the uterus, when segmentation of the yelk has reduced it down to the condition of fine granules, each one of the latter becomes surrounded by an envelope constituting it a true cell, in which the contained matter forms the nucleus. This happens first to the peripheral cells, which arrange themselves at the surface of the

yelk in the form of a membrane; other cells, as they are formed, are added to these, thereby increasing the thickness of the envelope, while the central portion of the yelk remains filled only with a clear fluid, the result, probably, of a deliquescence of the interior cells.

By this process a second kind of membrane is formed around the yelk, but within the zona pellucida or yelk bag; and as the whole structure of the future being is to be developed from this, it has been termed by Bischoff the *blastodermic vesicle*, or as it is generally called, the *germinal membrane*. Very soon after its formation, this membrane presents at one point an opaque roundish spot, which is produced by an accumulation of cells and nuclei of less transparency than elsewhere; this space is named the *germinal area*, and is the part at which the embryo first appears. The germinal membrane, in the higher animals, consists of three layers; the external one, which is formed first, is named the *serous;* from it are subsequently developed all the organs of animal life, as the muscles, bones and integuments; the internal layer is formed next, and called the *mucous;* from this originate the organs of organic life, as the stomach, intestines, lungs and glands; the intermediate one is formed last, and called *vascular*.

At its first appearance the germinal area has a rounded form, which, however, it soon loses, becoming oval and pear-shaped, and while this change is taking place, there appears in its centre a clear space termed the *area pellucida*, bounded externally by a more opaque circle—due to the greater accumulation of cells—called the *area vasculosa*, so named because it gives origin to the vascular system.

Thus we have the first development of the embryo into a *sac*, enclosing a store of nourishment; it is, in fact, a stomach enclosing its own aliment; for it is by means of the mucous layer of the germinal membrane, that the nutritious material is appropriated to the support of the embryo. In the lowest animals, as the Polypi, the process of embryotic development does not proceed much farther than this point; for the external layer of the germinal membrane becomes the *integument*, the internal layer, the

stomach, and the space occupied by the yelk, the *digestive cavity.* But in the higher animals, the greater part of the germinal membrane is destined to be thrown off as useless when it has performed its functions, like the cotyledons of a plant.

The above changes are taking place in the ovum, while it is passing through the Fallopian tube. During this transit, the mammalian ovum receives an addition analogous to the white of the egg of birds; and this is surrounded by a fibrous layer similar to the lining membrane of the eggshell: this envelope becomes the *chorion.* On its surface are seen numerous villi, or processes, which give it a shaggy appearance. These processes, which are composed of nucleated cells, act as absorbing radicles; and it is by this means that the embryo is nourished from the fluids of the parent, until a more perfect communication is established through the placenta.

The *membrana decidua* of the uterus is so named from its being cast off at each parturition. It is formed from the surface of the lining membrane, by means of epithelium-cells, which line the tubular follicles that are particularly numerous after fecundation. Its thickness is from one to three lines. It covers over the neck of the uterus and the orifices of the Fallopian tubes. It is formed when impregnation has occurred, whether the ovum has reached the uterus or not, as it is found in cases of extra-uterine pregnancy. At a later period, the decidua consists of two layers—the *decidua vera,* lining the cavity of the uterus, and the *decidua reflexa,* reflected over the ovum. The decidua reflexa was formerly supposed to be a portion of the decidua vera merely pushed before the ovum, and *developed* over it: but from the difference of their structure, it has probably a different origin. These two layers gradually come in contact as the ovum grows; and the space between them is usually obliterated at the third month, so that they cannot be distinguished from each other.

Formation of the Placenta.—It commences by the penetration of the villi of the chorion into the tubuli of the decidua. These villi serve as roots, to suck up and convey to the embryo the nourishment prepared by the maternal structure. This is the

earliest and simplest mode by which the fœtus forms a connexion with its mother, and it is the *only* one that takes place in the lower animals, called *non-placental.* In the higher animals, the tufts of the chorion form a vascular connexion with the fœtus by means of the *allantois*,—as will presently be seen; then the vascular tufts are particularly developed at a certain spot of the chorion, where they are collected in large numbers, forming the placenta. In some of the lower tribes the maternal and fœtal portions of the placenta can be distinguished, but in the human female the elements of the two are completely intermingled throughout. The fœtal portion of the placenta consists of the subdivisions of the umbilical vessels, the ultimate ramifications of which are in the form of villi, each containing a capillary vessel in the shape of a loop, and communicating with an artery and vein. The vessels of the placental villus are surrounded by cells enclosed in a basement-membrane. The *maternal* portion of the placenta consists of a prolongation of the internal coat of the great uterine vessels, forming a sort of enlarged sac. Against this sac the placental tufts project, so as to form out of it a sheath for themselves. The blood is conveyed into the placenta by the *curling arteries*,—so named from their peculiar course: they proceed from the uterine arteries, the blood being returned through the large uterine veins called *sinuses.*

Hence, there is no *direct* communication between the blood of the mother and that of the fœtus; the fœtal tufts, being bathed in the maternal blood, draw from it, by means of their cells, the proper materials for the nutrition of the embryo. They may be compared to the villi of the intestines, which dip down into the fluids of the alimentary canal, and by means of their cells, elaborate their appropriate materials. But they also perform another important function,—that of respiration for the embryo, by giving out their carbonic acid to the maternal blood, and receiving oxygen from it: in this respect the fœtal villi resemble the gills of fishes.

The formation of the human placenta commences about the end of the second month of utero-gestation, and acquires its proper

character during the third month. The vessels of the uterus become enlarged throughout, but particularly about the attachment of the placenta; and the blood in moving through them produces a peculiar purring sound, called *placental bruit*, which is heard as early as the twelfth week of pregnancy. It is synchronous with the pulse of the mother, and is a diagnostic sign of pregnancy.

Continuation of the Development of the Embryo.—The Nervous system is the first portion of the permanent structure which is seen. Its rudiment is exhibited in what is termed the *primitive groove* or *primitive trace*,—a shallow groove lying between two oval ridges, named *laminæ dorsales.* These are composed of masses of cells; their shape elongates with that of the area pellucida; at last they assume the appearance of a violin. Their borders gradually rise upwards, and approach each other until they finally coalesce, so as to convert the groove into a tube (Bischoff). Within this the cerebro-spinal axis is formed; the brain being developed in the dilated portion, and the spinal cord in the more contracted part. The former remains unclosed much longer than the latter. The tube thus formed, contains a number of cells arranged in a linear direction, named the *chorda dorsalis,* around which the vertebral column is developed.

The Vascular system begins to appear very soon after, or concurrently with, the first appearance of the nervous system. The first development is in the vascular layer of the germinal membrane, in the form of a very fine network of vessels, called the *vascular area.* This gradually extends itself till the vessels spread over the whole of the membrane. The *blood-disks* seem to originate from the nuclei of the cells of the vascular layer, whilst the first *vessels* are probably formed from the elongation of the cells. The vascular network serves to convey the nutritious matter of the yelk-bag to the embryo. The vessels of the yelk-bag terminate in two large trunks, called *omphalo-mesenteric* or *vitelline vessels,* which enter the embryo at the point that afterwards becomes the umbilicus. The first movement always takes place *towards* the embryo, and can be perceived before the heart is seen.

The *heart* is formed in the substance of the vascular layer, by a dilatation of the trunk into which the blood-vessels unite: this, shortly after, becomes bent upon itself; then it divides into cavities,—the walls gradually acquiring strength. In this early condition, the heart is known as the *punctum saliens.*

The Digestive system is developed along with the vascular. It commences by a doubling in of the mucous layer, under the abdomen of the fœtus, so as to enclose a cavity; this, by subsequent prolongation and involution, is moulded into the stomach and intestines. This digestive cavity communicates for some time with the yelk-bag, from which, in a measure, it has been pinched off, through the opening left by the imperfect closure of its walls. In the mammalia, this orifice is gradually narrowed, and at last completely closed; and the yelk-bag, thus separated, is afterwards thrown off. It is then named the *umbilical vesicle*, and may be detected upon the umbilical cord up to a late period of pregnancy.

Formation of the Amnion.—That part of the serous lamina of the germinal membrane surrounding the area pellucida rises up on each side in two folds; these gradually approach each other, in the space between the embryo and the chorion, so as to form an additional investment for the former. Each of these folds contain two layers of membrane; and by gradually enlarging themselves, the outer layer comes at length in contact with the inner layer of the chorion, and adheres to it; while the *inner* layer remains as a distinct sac: it is called the *Amnion*. Within it is contained the *liquor amnii*, which resembles dilute serum. The *Allantois* is a sort of process from the digestive cavity; at first it is a small vesicle, which, in birds, is subsequently prolonged so as to extend round the whole of the yelk-bag. Its *function* in the egg of birds is to aerate the fluid, through the membrane of the shell. In the ovum of the mammalia, its chief office is to convey the vessels of the embryo to the chorion, and its extent corresponds with the size of the placenta. When the attachment of the embryo to the uterine surface, by means of the placenta, has taken place, the allantois, being of no farther use, shrivels up so as scarcely to be seen. The lower part of the

allantois remains as the urinary bladder, and the duct by which it was connected with the abdominal cavity, becomes the *urachus* or suspensory ligament of the bladder.

The *umbilical cord* consists of:—1st. The umbilical vessels, comprising two arteries and one vein. 2d. The remains of the umbilical vesicle and duct. 3d. The omphalo-mesenteric vessels. 4th. The urachus. 5th. The investment of the whole, made from a reflection of the amnion.—The arteries are branches of the hypogastric; their function is to convey the blood of the fœtus to the placenta, to be revivified. The vein returns the blood to the fœtus, and empties partly into the vena portæ, and partly through the ductus venosus into the vena cava.

The *circulation* of the fœtus is somewhat similar in character to that of the higher reptiles; that is, the heart contains both arterial and venous blood, which is owing to the peculiar arrangement of the circulating system. The two auricles communicate through the *foramen ovale*, which remains open up to the period of birth, and, occasionally, even for some time after. There is also a direct communication, through the *ductus arteriosus*, between the aorta and pulmonary artery; and another direct channel between the umbilical vein and the vena cava, by the *ductus venosus*. By this arrangement, the head and upper extremities, whose development is required to be in advance of the rest of the body, receive nearly pure arterialized blood; the other portions being supplied with blood of a mixed character.

It is not quite certain upon what "*quickening*" depends, though it is commonly ascribed to the first movement of the fœtus in utero, or to the sudden rise of the uterus from the pelvis into the abdomen, in the fourth month.

The average *duration of pregnancy* in the human female is 40 weeks, or 280 days: it is occasionally prolonged from one to three weeks. By the law of France, 300 days are the limits assigned for a legitimate birth. Among the lower animals such prolongations are not unusual. It is not ascertained what is the cause of the departure from the general rule, but it is probably owing to some peculiarity in the male germ, as shown by observations made

by cattle-breeders upon cows in calf by a certain bull always exceeding their time, and some few coming short of it.

The shortest period at which gestation may terminate, consistently with the life of the child, is not determined, owing to the impossibility of exactly determining the time of conception. Although an infant is not usually considered *viable* if born before the end of the seventh month, there are cases on record of their living, though born in the twenty-fifth or twenty-sixth week.

The act of *parturition* is accomplished partly by the contractions of the uterus, and partly by the contraction of the muscles of the abdomen. Why it should occur just at one particular period is as much a matter of obscurity as other periodic phenomena. The term *labour* is applied to the expulsion of the fœtus. It is accomplished by the contractile efforts of the uterus itself, and aided by those of the abdominal muscles. The uterine contractions are called into action partly by the direct stimulation of its non-striated muscular fibres, and partly through reflex agency; the influence of the latter is shown by the immediate effect produced, in cases of imperfect uterine action, by the application of cold to the abdomen, and still more by the application of the child to the breast. The uterus also possesses sufficient independent power to expel its contents, as is shown in cases where the fœtus has been extruded after somatic death.

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THE END.